



## DECLARATION

I, Masami AIZAWA, of SHIGA INTERNATIONAL PATENT OFFICE, 2-3-1, Yaesu, Chuo-ku, Tokyo, Japan, understand both English and Japanese, am the translator of the English document attached, and do hereby declare and state that the attached English document contains an accurate translation of the official certified copy of Japanese Patent Application No. Hei 11-150024 and that all statements made herein are true to the best of my knowledge.

Declared in Tokyo, Japan

This 14<sup>th</sup> day of April, 2004

*Masami Aizawa*

Masami AIZAWA

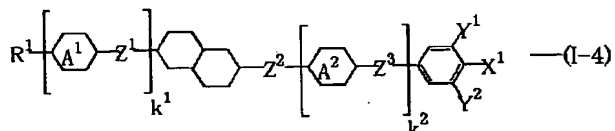
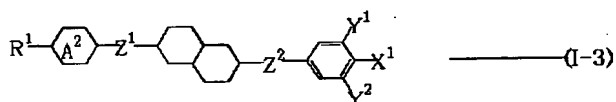
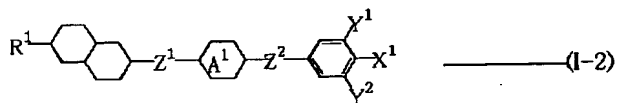
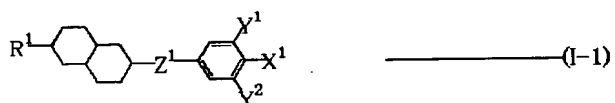
[Document Type] Specification

[Title of the Invention] NEMATIC LIQUID CRYSTAL COMPOSITION  
AND LIQUID CRYSTAL DISPLAY DEVICE USING THE SAME

[Claims]

[Claim 1] A nematic liquid crystal composition comprising a liquid crystal component A composed of one, or two or more kinds of compounds represented by one, two, or three or more general formulas selected from the general formulas (I-1) to (I-4):

[Chemical Formula 1]



(wherein one, or two or more  $-\text{CH}_2-$  groups, which are present in a decahydronaphthalene-2,6-diyl group, may be substituted with  $-\text{CF}_2-$ , one, or two or more  $-\text{CH}_2-\text{CH}_2-$  groups, which are present in said group, may be substituted with  $-\text{CH}_2\text{O}-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{CF}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{CH}=\text{N}-$  or  $-\text{CF}=\text{N}-$ , one, or two or more  $>\text{CH}-\text{CH}_2-$  groups, which are present in said group, may be substituted with  $>\text{CH}-\text{O}-$ ,  $>\text{C}=\text{CH}-$ ,  $>\text{C}=\text{CF}-$ ,  $>\text{C}=\text{N}-$  or  $>\text{N}-\text{CH}_2-$ , and  $>\text{CH}-\text{CH}<$  group, which is present in the ring, may

be independently substituted with  $>\text{CH}-\text{CF}<$ ,  $>\text{CF}-\text{CF}<$  or  $>\text{C}=\text{C}<$ ;

$\text{R}^1$  each independently represents an alkyl group having 1 to 10 carbon atoms or an alkenyl group having 2 to 10 carbon atoms, said alkyl or alkenyl group can have one F,  $-\text{CH}_3$  or  $-\text{CF}_3$  as a non-substituent or substituent group, and/or one, or two or more  $-\text{CH}_2-$  groups, which are present in said alkyl or alkenyl group, may be substituted with  $-\text{O}-$ ,  $-\text{CO}-$  or  $-\text{COO}-$ , while O atoms do not bond with each other directly;

$\text{X}^1$  each independently represents F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ ,  $-\text{OCF}_2\text{H}$ ,  $-\text{NCS}$ , or  $-\text{CN}$ ;

$\text{Y}^1$  and  $\text{Y}^2$  each independently represents H, F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ , or  $-\text{CN}$ ;

$\text{Z}^1$ ,  $\text{Z}^2$  and  $\text{Z}^3$  each independently represents a single bond,  $-\text{COO}-$ ,  $-\text{OCO}-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{C}\equiv\text{C}-$ ,  $-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_4-$ ,  $-\text{CH}=\text{CH}-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{N}-$ ,  $-\text{CH}=\text{N}-\text{N}=\text{CH}-$ , or  $-\text{N}(\text{O})=\text{N}-$ ;

rings  $\text{A}^1$  and  $\text{A}^2$  each independently represents 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, 3,5-difluoro-1,4-phenylene, pyrimidine-2,5-diyl, trans-1,4-cyclohexylene, trans-1,4-cyclohexenylene, or trans-1,3-dioxane-2,5-diyl;

one, or two or more hydrogen atoms, which are present in a decahydronaphthalene-2,6-diyl group and rings  $\text{A}^1$  and  $\text{A}^2$ , may be substituted with a deuterium atom;

$k^1$  and  $k^2$  each independently represents 0, 1 or 2, and  $k^1 + k^2$  is 2; and

atoms, which constitute the compounds of the general

formulas (I-1) to (I-4), may be substituted with isotope atoms thereof); 0 to 99.9% by weight of a liquid crystal component B composed of a compound having a dielectric constant anisotropy of +2 or more as a liquid crystal component excluding the compounds of the general formulas (I-1) to (I-4); and 0 to 85% by weight of a liquid crystal component C composed of a compound having a dielectric constant anisotropy within a range from -10 to +2; the sum total of said liquid crystal component B and said liquid crystal component C being within a range from 0 to 99.9% by weight.

[Claim 2] A nematic liquid crystal composition according to claim 1, wherein said liquid crystal component A contains one to twenty kinds of compounds selected from one, two, or three or more general formulas among the above formulas (I-1) to (I-4), the content of said compounds being within a range from 5 to 100% by weight.

[Claim 3] A nematic liquid crystal composition according to claim 1 or 2, wherein said liquid crystal component A contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (I-ai) to (I-avi), the content of said compounds being within a range from 10 to 100% by weight:

(I-ai) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 7 carbon atoms;

(I-a ii) compound in which  $X^1$  is F, Cl,  $-CF_3$ ,  $-OCF_3$ ,  $-OCF_2H$ , or  $-CN$ ;

(I-a iii) compound in which  $Y^1$  and  $Y^2$  represent is H, F, Cl, -

CF<sub>3</sub>, or -OCF<sub>3</sub>;

(I-aiv) compound in which Z<sup>1</sup>, Z<sup>2</sup> and Z<sup>3</sup> represent a single bond, -(CH<sub>2</sub>)<sub>2</sub>-, -COO-, or -C≡C-;

(I-av) compound in which rings A<sup>1</sup> and A<sup>2</sup> represent trans-1,4-cyclohexylene, 1,4-phenylene, 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene; and

(I-avi) compound in which at least one of rings A<sup>1</sup> and A<sup>2</sup> is substituted with a deuterium atom if the rings A<sup>1</sup> and A<sup>2</sup> represent trans-1,4-cyclohexylene, in the general formulas (I-1) to (I-4).

[Claim 4] A nematic liquid crystal composition according to claim 1 or 2, wherein said liquid crystal component A contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (I-bi) to (I-bviii), the content of said compounds being within a range from 5 to 100% by weight, if said liquid crystal component A contains the compound of the above general formula (I-1):

(I-bi) compound in which R<sup>1</sup> is an alkenyl group having 2 to 7 carbon atoms;

(I-bii) compound in which one of Y<sup>1</sup> and Y<sup>2</sup> is F, Cl, -CF<sub>3</sub>, or -OCF<sub>3</sub>;

(I-biii) compound in which Z<sup>1</sup> is -(CH<sub>2</sub>)<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, or -C≡C-;

(I-biv) compound in which a decahydronaphthalene-2,6-diyl group has at least one substituent among substituents -CH<sub>2</sub>-O-, -CH=CH-, -CH=CF-, -CF=CF-, -CH=N-, -CF=N-, >CH-O-, >C=CH-, >C=CF-, >C=N-, >N-CH<sub>2</sub>-, >CH-CF<, >CF-CF, or >C=C<, in the

compounds in which  $X^1$  is  $-\text{CN}$ ;

(I-bv) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms;

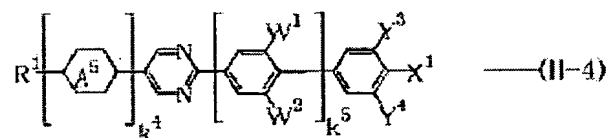
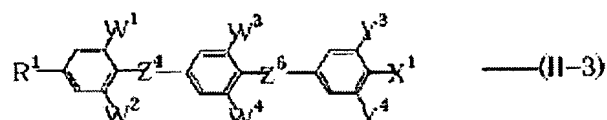
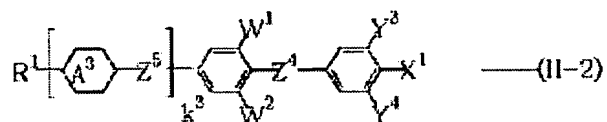
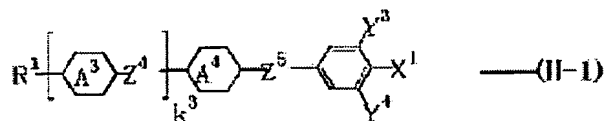
(I-bvi) compound in which one of  $Y^1$  and  $Y^2$  is H, F, Cl,  $-\text{CF}_3$ , or  $-\text{OCF}_3$ ;

(I-bvii) compound in which  $Z^1$  is a single bond,  $-(\text{CH}_2)_2-$ , or  $-\text{C}\equiv\text{C}-$ ;

(I-bviii) compound in which a decahydronaphthalene-2,6-diyl group has at least one substituent among substituents  $-\text{CH}_2-\text{O}-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{CF}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{CH}=\text{N}-$ ,  $-\text{CF}=\text{N}-$ ,  $>\text{CH}-\text{O}-$ ,  $>\text{C}=\text{CH}-$ ,  $>\text{C}=\text{CF}-$ ,  $>\text{C}=\text{N}-$ ,  $>\text{N}-\text{CH}_2-$ ,  $>\text{CH}-\text{CF}<$ ,  $>\text{CF}-\text{CF}<$ , or  $>\text{C}=\text{C}<$ , in the compounds in which  $X^1$  is F, Cl,  $-\text{CF}_3$ , or  $-\text{OCF}_3$ .

[Claim 5] A nematic liquid crystal composition according to claim 1, 2, 3 or 4, wherein said liquid crystal component B contains one, or two or more kinds of compounds selected from the group of compounds represented by the general formulas (II-1) to (II-4):

## [Chemical Formula 2]



(wherein  $R^1$  and  $X^1$  are as defined in claim 1;

$Y^3$  and  $Y^4$  each independently represents H, F, Cl, or -  
OCF<sub>3</sub>,

$W^1$ ,  $W^2$ ,  $W^3$  and  $W^4$  each independently represents H, F, or  
Cl;

$Z^4$ ,  $Z^5$  and  $Z^6$  each independently represents a single  
bond, -COO-, -OCO-, -CH<sub>2</sub>O-, -OCH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-, -CH=CH-  
(CH<sub>2</sub>)<sub>2</sub>-, -(CH<sub>2</sub>)<sub>2</sub>-CH=CH-, -CH=N-, =CH=N-N=CH-, or -N(O)=N-, and  
 $Z^4$  and  $Z^6$  each independently represents -CH=CH-, -CF=CF-, or C  
≡C-;

rings  $A^3$ ,  $A^4$  and  $A^5$  each independently represents trans-  
1,4-cyclohexylene, trans-1,4-cyclohexenylene, or trans-1,3-  
dioxane-2,5-diyl, and the ring  $A^5$  may also be 1,4-phenylene,  
2- or 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene,  
and one, or two or more hydrogen atoms, which are present in

rings A<sup>3</sup>, A<sup>4</sup> and A<sup>5</sup>, may be substituted with a deuterium atom;

k<sup>3</sup>, k<sup>4</sup> and k<sup>5</sup> each independently represents 0 or 1, and k<sup>4</sup> + k<sup>5</sup> is 0 or 1; and

atoms, which constitute the compounds of the general formulas (II-1) to (II-4), may be substituted with isotope atoms thereof).

[Claim 6] A nematic liquid crystal composition according to claim 5, wherein said liquid crystal component B contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (II-ai) to (II-axii), the content of said compounds being within a range from 10 to 100% by weight:

(II-ai) compounds in which R<sup>1</sup> is an alkenyl group having 2 to 5 carbon atoms, in the general formulas (II-1) to (II-4);

(II-a ii) compounds in which X<sup>1</sup> is F, Cl, or -OCF<sub>3</sub>, in the general formulas (II-1) to (II-4);

(II-a iii) compounds in which Z<sup>5</sup> is -(CH<sub>2</sub>)<sub>2</sub>- or -(CH<sub>2</sub>)<sub>4</sub>-, in the general formula (II-1);

(II-a iv) compound in which k<sup>3</sup> is 1, in the general formula (II-1);

(II-a v) compound in which at least one of Y<sup>3</sup>, Y<sup>4</sup>, W<sup>1</sup> and W<sup>2</sup> is F, in the general formula (II-2);

(II-a vi) compound in which k<sup>3</sup> is 1 and Z<sup>4</sup> is -C≡C-, in the general formula (II-2);

(II-a vii) compound in which Z<sup>5</sup> is a single bond or -(CH<sub>2</sub>)<sub>2</sub>- and Z<sup>4</sup> is -COO-, in the general formula (II-2);

(II-a viii) compound in which at least one of Y<sup>3</sup>, Y<sup>4</sup>, W<sup>1</sup>, W<sup>2</sup>, W<sup>3</sup>



and  $W^4$  is F, in the general formula (II-3);

(II-aix) compound in which  $Z^6$  is  $-C\equiv C-$ , in the general formula (II-3);

(II-ax) compound in which  $Z^4$  is a single bond or  $-C\equiv C-$  and  $Z^6$  is  $-COO-$ , in the general formula (II-3);

(II-axi) compound represented by the general formula (II-4);

and

(II-axii) compound in which at least one of rings  $A^3$ ,  $A^4$  and  $A^5$  is substituted with a deuterium atom if the rings  $A^3$ ,  $A^4$  and  $A^5$  represent trans-1,4-cyclohexylene, in the general formulas (II-1), (II-2) and (II-4).

[Claim 7] A nematic liquid crystal composition according to claim 5, wherein said liquid crystal component B contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (II-bi) to (II-bviii), the content of said compounds being within a range from 10 to 100% by weight:

(II-bi) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $X^1$  is  $-CN$ , in the general formula (II-1);

(II-bii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $X^1$  is F or  $-CN$ , and  $Y^3$  and  $Y^4$  each independently represent H or F, in the general formula (II-1);

(II-biii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 0,  $X^1$  is  $-CN$ , and  $Y^3$ ,  $Y^4$ ,  $W^1$  and  $W^2$  represent H or F, in the general formula (II-2);

(II-biv) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^5$  is a single bond,  $-(CH_2)_2-$ , or  $-COO-$ ,  $Z^4$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ ,  $X^1$  is F or  $-CN$ , and  $Y^3$ ,  $Y^4$ ,  $W^1$  and  $W^2$  represent H or F, in the general formula (II-2);

(II-bv) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, and one of  $Z^4$  and  $Z^6$  is a single bond and other one is a single bond,  $-COO-$ , or  $-C\equiv C-$ , in the general formula (II-3);

(II-bvi) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, and  $Y^3$ ,  $Y^4$ ,  $W^1$ ,  $W^2$ ,  $W^3$  and  $W^4$  represent H or F, in the general formula (II-3);

(II-bvii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 7 carbon atoms, and  $k^4+k^5=0$ , in the general formula (II-4); and

(II-bviii) compounds in which at least one hydrogen atom of rings  $A^3$  and  $A^4$  is substituted with a deuterium atom if the rings  $A^3$  and  $A^4$  represent trans-1,4-cyclohexylene, in the general formulas (II-1) to (II-2).

[Claim 8] A nematic liquid crystal composition according to claim 5, wherein said liquid crystal component B contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (II-ci) to (II-civ), the content of said compounds being within a range from 10 to 100% by weight:

(II-ci) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1, one of  $Z^4$  and  $Z^5$  is a

single bond and other one is a single bond,  $-\text{COO}-$ ,  $-(\text{CH}_2)_2-$ , or  $-(\text{CH}_2)_4$ ,  $\text{X}^1$  is F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ , or  $-\text{OCF}_2\text{H}$ , and one, or two or more of  $\text{Y}^3$  and  $\text{Y}^4$  represent F, in the general formula (II-1);

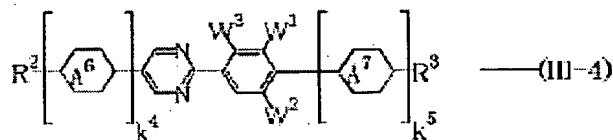
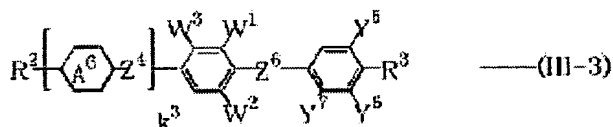
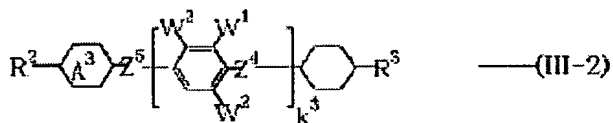
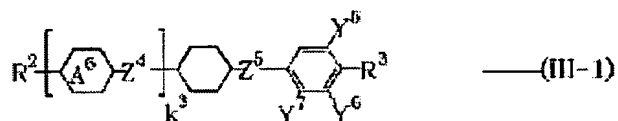
(II-cii) compound in which  $\text{R}^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $\text{Z}^5$  is a single bond,  $-(\text{CH}_2)_2-$ , or  $-\text{COO}-$ ,  $\text{Z}^4$  is a single bond,  $-\text{COO}-$ , or  $-\text{C}\equiv\text{C}-$ ,  $\text{X}^1$  is F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ , or  $-\text{OCF}_2\text{H}$ , one, or two or more of  $\text{Y}^3$  and  $\text{Y}^4$  represent F, and  $\text{W}^1$  and  $\text{W}^2$  represent H or F, in the general formula (II-2);

(II-ciii) compound in which  $\text{R}^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, one of  $\text{Z}^4$  and  $\text{Z}^6$  is a single bond and the other one is a single bond,  $-\text{COO}-$ , or  $-\text{C}\equiv\text{C}-$ ,  $\text{X}^1$  is F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ , or  $-\text{OCF}_2\text{H}$ , one, or two or more of  $\text{Y}^3$  and  $\text{Y}^4$  represent F, and  $\text{W}^1$ ,  $\text{W}^2$ ,  $\text{W}^3$  and  $\text{W}^4$  represent H or at least one of them is F, in the general formula (II-3); and

(II-civ) compounds in which at least three hydrogen atoms of rings  $\text{A}^3$  and  $\text{A}^4$  are substituted with a deuterium atom if the rings  $\text{A}^3$  and  $\text{A}^4$  represent trans-1,4-cyclohexylene, in the general formulas (II-1) and (II-2).

[Claim 9] A nematic liquid crystal composition according to claim 1, 2, 3, 4, 5, 6, 7 or 8, wherein said liquid crystal component C contains compounds selected from the group of compounds represented by the general formulas (III-1) to (III-4):

## [Chemical Formula 3]



(wherein  $W^1$  to  $W^3$ ,  $Z^4$  to  $Z^6$ , ring  $A^3$ , and  $k^3$  to  $k^5$  are as defined in claims 1 and 5;

$R^2$  and  $R^3$  each independently represents an alkyl or alkoxy group having 1 to 7 carbon atoms or an alkenyl or alkenyloxy group having 2 to 7 carbon atoms, said alkyl, alkoxy, alkenyl or alkenyloxy group can have one F,  $-\text{CH}_3$  or  $-\text{CF}_3$  as a non-substituent or substituent group, and/or one, or two or more  $-\text{CH}_2-$  groups, which are present in said alkyl, alkoxy, alkenyl or alkenyloxy group, may be substituted with  $-\text{O}-$ ,  $-\text{CO}-$  or  $-\text{COO}-$ , while O atoms do not bond with each other directly;

$Y^5$ ,  $Y^6$  and  $Y^7$  each independently represents H, F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ , or  $-\text{CN}$ , and  $Y^7$  each independently represents  $-\text{CH}_3$ ;

rings  $A^6$  and  $A^7$  each independently represents trans-1,4-cyclohexylene, trans-1,4-cyclohexenylene or trans-1,3-dioxane-2,5-diyl, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene;

one, or two or more hydrogen atoms, which are present in rings A<sup>3</sup>, A<sup>6</sup> and A<sup>7</sup>, may be substituted with a deuterium atom; and

atoms, which constitute the compounds of the general formulas (III-1) to (III-4), may be substituted with isotope atoms thereof).

[Claim 10] A nematic liquid crystal composition according to claim 9, wherein said liquid crystal component C contains one, or two or more kinds of compounds selected from compounds represented by the general formula (III-1), and/or compounds represented by the general formula (III-2), and/or compounds represented by the general formula (III-3), the content of said compounds being within a range from 10 to 100% by weight.

[Claim 11] A nematic liquid crystal composition according to claim 9, wherein said liquid crystal component C contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (III-ai) to (III-axii), the content of said compounds being within a range from 10 to 100% by weight:

(III-ai) compounds in which R<sup>2</sup> is an alkenyl group having 2 to 5 carbon atoms, in the general formulas (III-1) to (III-4);

(III-a ii) compounds in which R<sup>3</sup> is a straight-chain alkenyl or alkenyloxy group having 2 to 7 carbon atoms, in the general formulas (III-1) to (III-4);

(III-a iii) compounds in which k<sup>3</sup> is 0 and Z<sup>5</sup> is a single bond or -(CH<sub>2</sub>)<sub>2</sub>-, in the general formula (III-1);

(III-a iv) compound in which k<sup>3</sup> is 1, in the general formula

(III-1);

(III-av) compound represented by the general formula (III-2);

(III-avi) compound in which at least one of  $Y^5$ ,  $Y^6$ ,  $W^1$ ,  $W^2$  and  $W^3$  is F, in the general formula (III-3);

(III-avii) compound in which  $Y^7$  is F or  $-CH_3$ , in the general formula (III-3);

(III-aviii) compound in which  $k^3$  is 0 and  $Z^6$  is a single bond, in the general formula (III-3);

(III-aix) compound in which  $k^3$  is 1,  $Z^4$  is a single bond,  $-OCO-$ ,  $-CH_2O-$ ,  $-OCH_2-$ ,  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ ,  $-CH=CH-(CH_2)_2-$ ,  $-(CH_2)_2-CH=CH-$ ,  $-CH=N-$ ,  $-CH=N-N=CH-$ ,  $-N(O)=N-$ ,  $-CH=CH-$ , or  $-CF=CF-$ , in the general formula (III-3);

(III-ax) compound in which  $Z^4$  is  $-COO-$  or  $-C\equiv C-$  and  $Z^6$  is  $-OCO-$ ,  $-CH_2O-$ ,  $-OCH_2-$ ,  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ ,  $-CH=CH-(CH_2)_2-$ ,  $-(CH_2)_2-CH=CH-$ ,  $-CH=N-$ ,  $-CH=N-N=CH-$ ,  $-N(O)=N-$ ,  $-CH=CH-$ ,  $-CF=CF-$ , or  $-C\equiv C-$ , in the general formula (III-3);

(III-axi) compound represented by the general formula (III-4);  
and

(III-axii) compounds in which at least one hydrogen atom of rings  $A^3$ ,  $A^6$  and  $A^7$  is substituted with a deuterium atom if the rings  $A^3$ ,  $A^6$  and  $A^7$  represent trans-1,4-cyclohexylene, in the general formulas (III-1) to (III-4).

[Claim 12] A nematic liquid crystal composition according to claim 9, wherein said liquid crystal component C contains one to twenty kinds of compounds selected from one, two, or

three or more sub-groups among the following sub-groups (III-bi) to (III-bix), the content of said compounds being within a range from 10 to 100% by weight:

(III-bi) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $Z^5$  is a single bond,  $-COO-$ , or  $-(CH_2)_2$ , in the general formula (III-1);

(III-bii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1, the ring  $A^6$  is trans-1,4-cyclohexylene, and one of  $Z^4$  and  $Z^5$  is a single bond and other one is a single bond,  $-COO-$ , or a  $-(CH_2)_2-$ , in the general formula (III-1);

(III-biii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, the ring  $A^3$  is trans-1,4-cyclohexylene or trans-1,4-cyclohexenylene,  $k^3$  is 0, and  $Z^5$  is a single bond,  $-COO-$ , or  $-(CH_2)_2-$ , in the general formula (III-2);

(III-biv) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, the

ring  $A^3$  is trans-1,4-cyclohexylene or trans-1,4-cyclohexenylene,  $k^3$  is 1, and one of  $Z^4$  and  $Z^5$  is a single bond, in the general formula (III-2);

(III-bv) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $Z^6$  is a single bond,  $-C\equiv C-$ , or  $-CH=N-N=CH-$ , in the general formula (III-3);

(III-bvi) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^4$  is a single bond,  $-(CH_2)_2-$ ,  $-COO-$ , or  $-C\equiv C-$ , and  $Z^6$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ , in the general formula (III-3);

(III-bvii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1, one of  $Z^4$  and  $Z^6$  is a single bond and other one is a single bond or  $-C\equiv C-$ , and at least one of  $W^1$  and  $W^2$  is F, in the general formula (III-3);

(III-bviii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, and



any one of  $Y^6$  and  $Y^7$  is substituted with F or  $-CH_3$ , in the general formula (III-3); and

(III-bix) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkyloxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, and  $k^4+k^5=0$ , in the general formula (III-4).

[Claim 13] A nematic liquid crystal composition according to any one of claims 1 to 12, wherein said liquid crystal composition contains one, or two or more kinds of core-structure compounds which have four six-membered rings and a liquid crystal phase-isotropic liquid phase transition temperature of  $100^\circ\text{C}$  or higher.

[Claim 14] A nematic liquid crystal composition according to any one of claims 1 to 13, wherein said liquid crystal composition has a dielectric constant anisotropy within a range from 2 to 40, a birefringent index within a range from 0.02 to 0.40, a nematic phase-isotropic liquid phase transfer temperature within a range from  $50$  to  $180^\circ\text{C}$  or higher, and a crystal phase-, smectic phase- or glass phase-nematic phase transfer temperature within a range from  $-200$  to  $0^\circ\text{C}$ .

[Claim 15] A nematic liquid crystal composition according to any one of claims 1 to 14, wherein said liquid crystal composition contains a compound having an optically active group capable of securing an induced helical pitch within a range from  $0.5$  to  $1000\text{ }\mu\text{m}$ .

[Claim 16] An active matrix, twisted nematic or super

twisted nematic liquid display device using the nematic liquid crystal composition of claim 15.

[Claim 17] A light scattering type liquid display device comprising a light modulation layer which contains the liquid crystal composition of any one of claims 1 to 15 and a transparent solid substance.

[Claim 18] A light scattering type liquid display device according to claim 17, wherein said liquid crystal composition formed a continuous layer in said light modulation layer and said transparent solid substance formed a uniform three-dimensional network in said continuous layer.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to nematic liquid crystal compositions which are useful as electro-optical display materials, and a liquid crystal display device using the same.

[0002]

[Prior Art]

Representative liquid crystal display elements include TN-LCDs (twisted nematic liquid crystal display element), that is used in clocks, electronic calculators, handheld organizers, pocket computers, word processors and personal computers. As the volume of information processed by office automation equipment increased, the STN (super twisted nematic) LCD was developed by Scheffer et al. (SID '85 Digest, p. 120, 1985) and Kinugawa et al. (SID '86 Digest, p.

122, 1986), and found wide use in portable terminals, handheld organizers, pocket computers, word processors, personal computers and display terminals for sophisticated information processing.

[0003]

Recently, the active addressing drive method (Proc. 12<sup>th</sup> IDRC p. 503, 1992) and multi-alignment addressing drive method (SID '92 Digest, p. 232, 1992) have been proposed for improving the response characteristics of STN-LCDs. For the purpose of providing displays with a higher brightness and higher contrast ratio, the use of a modified reflection type color LCD display method (Television Association Technical Report, vol. 14, No. 10, p.51, 1990) that utilizes the birefringence of a liquid crystal and a retardation plate instead of a color filter, and a liquid crystal display device provided with a reflecting surface having small parabolic surfaces formed on the substrate electrode side have been proposed.

[0004]

For application to large display areas, in particular, it is required to achieve uniformity of the display, despite the temperature distribution of the backlight, and high contrast. This calls for a liquid crystal material that has more stable orientation and lower dependence on the temperature, or an appropriate birefringent index for limiting the variations in the cell thickness. Also because the display is driven with a higher duty ratio as the number of pixels increases, it is

required to improve the response characteristics and the display tone characteristics accordingly. For the medium- and small displays for portable applications, on the other hand, it is important to achieve stability of the display regardless of the operating temperature. This calls for a liquid crystal material that allows a lower driving voltage in order to improve the response characteristics and reduce the power consumption, lower temperature dependence of the driving voltage in extreme temperature ranges from  $-30$  to  $0^{\circ}\text{C}$  and  $40$  to  $80^{\circ}\text{C}$ , higher sharpness and lower frequency dependence for driving with the desired duty ratio in the temperature range. Moreover, although it should be avoided to make the electric resistance (resistivity) of the liquid crystal too low to decrease the power consumption, the resistivity should be set to a proper level that is not high enough to cause burning of the display. Thus there still remain various requirements for improved liquid crystal materials having slightly different characteristics that are different from each other.

[0005]

For this purpose, the liquid crystal material is required to have an optimized set of characteristics including physical properties such as birefringent index, elastic constant, dielectric constant anisotropy, lower viscosity, broader nematic temperature range, chemical stability and electrical stability (a desired resistivity and voltage holding ratio), a pre-tilt angle related to the orientation and a wider d/p margin. Accordingly, there are still demands for new liquid

crystal compounds and liquid crystal compositions.

[0006]

Meanwhile, active matrix liquid crystal display devices have been used for such applications as portable terminals, liquid crystal television screens, projectors and computers, by taking advantage of the high display quality thereof. In the active matrix liquid crystal display device, a TFT (thin film transistor), an MIM (metal-insulator-metal) element or the like is used for each pixel, and a high voltage holding ratio is required for this display method. For the purpose of achieving a wider viewing angle, a super TFT that combines the IPS mode was proposed by Kondo et al. (Asia Display '95 Digest, p. 707, 1995). (The liquid crystal display elements of the active matrix display method will be hereinafter collectively referred to as TFT-LCDs.) In order to provide for such new display elements, various proposals have been made of new liquid crystal compounds and new liquid crystal compositions, such as Japanese Unexamined Patent Application, First Publication No. Hei 2-233626 and Published Japanese Translation No. Hei 4-501575 of the PCT Application.

[0007]

In order to provide for a TFT-LCD based on polysilicon technology, which has been a focus of attention recently, there are demands for a liquid crystal material having a higher voltage holding ratio and higher immunity to staining, and a liquid crystal material having faster response characteristics with a lower driving voltage. Requirements

are becoming further differentiated, such as a liquid crystal materials with lower possibilities of display defects, in order to improve the production yield, and liquid crystal materials capable of providing greater pre-tilt angles.

[0008]

As a liquid crystal material capable of providing a brighter display and higher contrast without the need for a polarizer plate or an alignment treatment process, liquid crystal display elements made by dispersing liquid crystal droplets in a polymer are disclosed in Published Japanese Translation No. Sho 58-501631 of the PCT Application, U.S. Patent No. 4,435,047, Published Japanese Translation No. Sho 61-502128 of the PCT Application, Japanese Unexamined Patent Application, First Publication No. Sho 62-2231, and the like. (These liquid crystal display elements will be hereinafter collectively referred to as PDLCs.) These elements have such problems that it is necessary to optimize the birefringences of the liquid crystal materials and the birefringence of the polymer, and a high voltage is required to achieve sufficient transparency. On the other hand, in order to achieve low-voltage drive capability, high contrast and multiplexing drive, U.S. Patent No. 5,304,323 and Japanese Unexamined Patent Application, First Publication No. Hei 1-198725 disclose liquid crystal display elements having such a structure that the liquid crystal material forms a continuous layer and a polymer is distributed in the continuous layer in a three-dimensional network structure. (This liquid crystal

display element will be hereinafter referred to as a PN-LCD.)

[0009]

For a liquid crystal material used for the purpose described above, European Patent Publication No. 359,146 discloses a method for optimizing the birefringent index and dielectric constant anisotropy of the liquid crystal material, Japanese Unexamined Patent Application, First Publication No. Hei 6-222320 discloses a technology to set a particular elastic constant of the liquid crystal material, and Japanese Unexamined Patent Application, First Publication No. Hei 5-339573 discloses the use of a fluoro compound. However, there remain problems in the voltage holding ratio with high resistance, low driving voltage, contrast ratio related to the intensity of light scattering, response speed, temperature characteristics and other properties, and development efforts are still being made.

[0010]

As described above, liquid crystal display elements are still required to have a capability to display with higher resolution and higher density, faster response speed for a driving voltage and ambient temperature, lower driving voltage with high chemical and electrical stability, higher tone display characteristics, and higher contrast for the operating temperature and view angle. For this purpose, research and development activities are underway to find liquid crystal materials that have nematic characteristics over a wide temperature range, maintain the nematic phase for a long

period of time while being stored at a low temperatures, with a lower viscosity that allows improved response characteristics and capable of operating at a desired driving voltage, particularly at a lower driving voltage. Efforts for improvements are also focused on the design and temperature dependence of the birefringent index, dielectric constant anisotropy, elastic constant, light wavelength dependence of the birefringent index, and frequency dependency of the dielectric constant anisotropy in correspondence to the duty number.

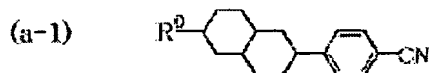
[0011]

As compounds related to the general formulas (I-1) to (I-4) of the present invention, compounds of the following general formulas (a-1) to (a-2) are described. For example, compounds of the general formula (a-1) are disclosed in Japanese Unexamined Patent Application, First Publication No. Sho 57-1309291 (1982), German Patent Application No. 3150312A (1982), GB Patent Application No. 2090593A (1982) and U.S. Patent No. 4,432,885A (1984); and compounds of the general formula (a-2) are disclosed in German Patent Application No. 156258A (1982), U.S. Patent No. 4,391,731A (1983) and Japanese Unexamined Patent Application, First Publication No. Sho 57-54130 (1982) (wherein R<sup>0</sup> represents an alkyl group).



[0012]

[Chemical Formula 4]



[0013]

However, techniques related to the characteristics required at present are scarcely known. In detail, the dielectric constant anisotropy, birefringent index, elastic constant and viscosity of compounds of general formulas (a-1) to (a-2) are not known. Although general advantages of the compounds are described, no technical knowledge related to TN-LCDs, STN-LCDs and TFT-LCDs, which would enable a person with ordinary skill in the art to use them easily, is disclosed.

[0014]

Furthermore, although the compositions are generally described in Published Japanese Translation No. Hei 4-502781 (1992) of the PCT Application, WO 91-05029 (1991) and U.S. Patent No. 5,487,845, specific examples thereof are not disclosed. Accordingly, application examples using the liquid crystal composition, e.g. specific examples related to liquid crystal display elements, liquid crystal display devices or the like are not disclosed.

[0015]

[Problems to be Solved by the Invention]

The present invention is directed to a nematic liquid crystal composition containing at least one of the compounds represented by the general formulas (I-1) to (I-4) and, more particularly, to a nematic liquid crystal composition containing one, or two or more kinds of compounds of the general formulas (I-1) to (I-4), or a compound in which any one among decahydronaphthalene-2,6-diyl groups is substituted. The present invention intends to meet the requirements for the liquid crystal materials described above, or improve their properties, with a combination of these with compounds other than the compounds of the general formulas (I-1) to (I-4), thus improving the characteristics of the liquid crystal display elements described above.

[0016]

More particularly, the present invention intends to extend the operating temperature of the liquid crystal display by making improvements in the co-solubility and in the storage at low temperature, and to remedy the reduction in driving voltage and the change in temperature, thereby to attain comparatively fast response characteristics or to improve the response characteristics for a predetermined driving voltage. Also the present invention intends to improve various display characteristics of MIM or TFT-LCDs or PDLCs by a liquid crystal material having a desired birefringent index and to improve display characteristics of PN-LCDs or PDLCs by a liquid crystal material having a comparatively large birefringent index.

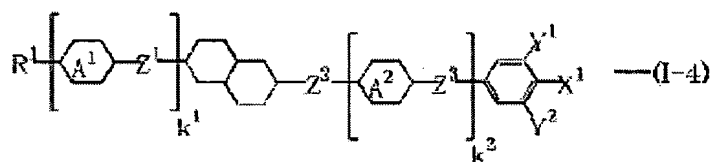
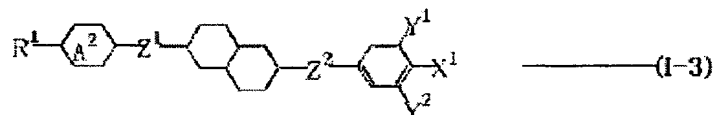
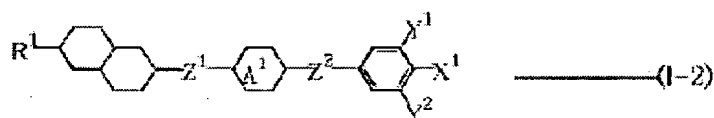
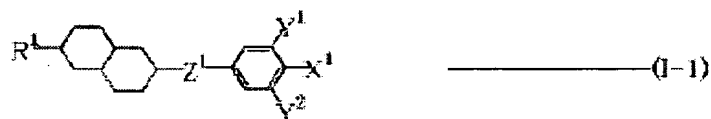
[0017]

## [Means for Solving the Problems]

To solve the problems described above, the present invention provides a nematic liquid crystal composition comprising a liquid crystal component A composed of one, or two or more kinds of compounds represented by one, two, or three or more general formulas selected from the general formulas (I-1) to (I-4):

[0018]

## [Chemical Formula 5]



[0019]

(wherein one, or two or more  $-\text{CH}_2-$  groups, which are present in a decahydronaphthalene-2,6-diyl group, may be substituted with  $-\text{CF}_2-$ , one, or two or more  $-\text{CH}_2\text{CH}_2-$  groups, which are present in said group, may be substituted with  $-\text{CH}_2\text{O}-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{CF}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{CH}=\text{N}-$  or  $-\text{CF}=\text{N}-$ , one, or two or more  $>\text{CH}-\text{CH}_2-$  groups, which are present in said group,

may be substituted with  $>\text{CH}-\text{O}-$ ,  $>\text{C}=\text{CH}-$ ,  $>\text{C}=\text{CF}-$ ,  $>\text{C}=\text{N}-$  or  $>\text{N}-\text{CH}_2-$ , a  $>\text{CH}-\text{CH}<$  group, which is present in the group, may be independently substituted with  $>\text{CH}-\text{CF}<$ ,  $>\text{CF}-\text{CF}<$  or  $>\text{C}=\text{C}<$ ;

$\text{R}^1$  each independently represents an alkyl group having 1 to 10 carbon atoms or an alkenyl group having 2 to 10 carbon atoms, said alkyl or alkenyl group can have one F,  $-\text{CH}_3$  or  $-\text{CF}_3$  as a non-substituent or substituent group, and/or one, or two or more  $-\text{CH}_2-$  groups, which are present in said alkyl or alkenyl group, may be substituted with  $-\text{O}-$ ,  $-\text{CO}-$  or  $-\text{COO}-$ , while O atoms do not bond with each other directly;

$\text{X}^1$  each independently represents F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ ,  $-\text{OCFH}_2$ ,  $-\text{NCS}$ , or  $-\text{CN}$ ;

$\text{Y}^1$  and  $\text{Y}^2$  each independently represents H, F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ , or  $-\text{CN}$ ;

$\text{Z}^1$ ,  $\text{Z}^2$  and  $\text{Z}^3$  each independently represents a single bond,  $-\text{COO}-$ ,  $-\text{OCO}-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{C}\equiv\text{C}-$ ,  $-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_4-$ ,  $-\text{CH}=\text{CH}-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{N}-$ ,  $-\text{CH}=\text{N}-\text{N}=\text{CH}-$ , or  $-\text{N}(\text{O})=\text{N}-$ ;

rings  $\text{A}^1$  and  $\text{A}^2$  each independently represents 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, 3,5-difluoro-1,4-phenylene, pyrimidine-2,5-diyl, trans-1,4-cyclohexylene, trans-1,4-cyclohexenylene, or trans-1,3-dioxane-2,5-diyl;

one, or two or more hydrogen atoms, which are present in a decahydronaphthalene-2,6-diyl group and rings  $\text{A}^1$  and  $\text{A}^2$ , may be substituted with a deuterium atom;

$k^1$  and  $k^2$  each independently represents 0, 1 or 2, and  $k^1$

+  $k^2$  is 2; and

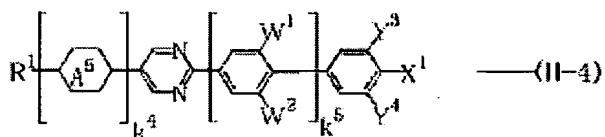
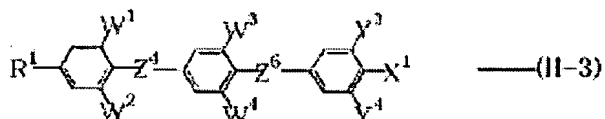
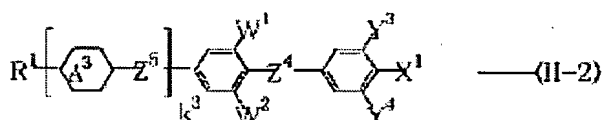
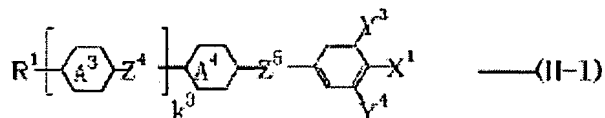
atoms, which constitute the compounds of the general formulas (I-1) to (I-4), may be substituted with isotope atoms thereof); 0 to 99.9% by weight of a liquid crystal component B composed of a compound having a dielectric constant anisotropy of +2 or more as a liquid crystal component excluding the compounds of the general formulas (I-1) to (I-4); and 0 to 85% by weight of a liquid crystal component C composed of a compound having a dielectric constant anisotropy within a range from -10 to +2; the sum total of said liquid crystal component B and said liquid crystal component C being within a range from 0 to 99.9% by weight.

[0020]

The liquid crystal component B according to the present invention can contain one, or two or more kinds of compounds selected from the group of compounds represented by the general formulas (II-1) to (II-4):

[0021]

[Chemical Formula 6]



[0022]

(wherein  $R^1$  and  $X^1$  are as defined above;

$Y^3$  and  $Y^4$  each independently represents H, F, Cl, or  $-\text{OCF}_3$ ,

$W^1$ ,  $W^2$ ,  $W^3$  and  $W^4$  each independently represents H, F, or Cl;

$Z^4$ ,  $Z^5$  and  $Z^6$  each independently represents a single bond,  $-\text{COO}-$ ,  $-\text{OCO}-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_4-$ ,  $-\text{CH}=\text{CH}-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{N}-$ ,  $=\text{CH}=\text{N}-\text{N}=\text{CH}-$ , or  $-\text{N}(\text{O})=\text{N}-$ , and  $Z^4$  and  $Z^6$  each independently represents  $-\text{CH}=\text{CH}-$ ,  $-\text{CF}=\text{CF}-$ , or  $\text{C}\equiv\text{C}-$ ;

rings  $A^3$ ,  $A^4$  and  $A^5$  each independently represents trans-1,4-cyclohexylene, trans-1,4-cyclohexenylene, or trans-1,3-dioxane-2,5-diyl, and the ring  $A^5$  may also be 1,4-phenylene,

2- or 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene, and one, or two or more hydrogen atoms, which are present in rings A<sup>3</sup>, A<sup>4</sup> and A<sup>5</sup>, may be substituted with a deuterium atom;

k<sup>3</sup>, k<sup>4</sup> and k<sup>5</sup> each independently represents 0 or 1, and k<sup>4</sup> + k<sup>5</sup> is 0 or 1; and

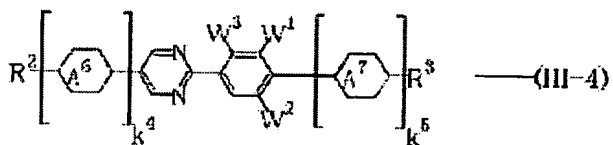
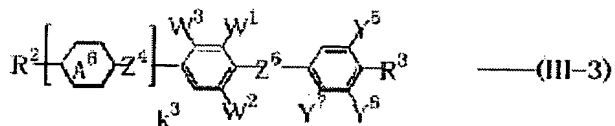
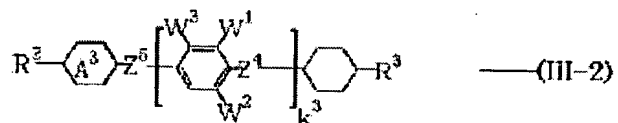
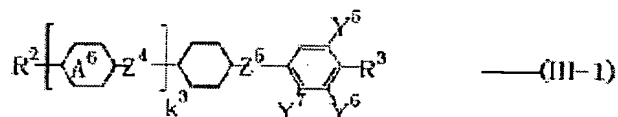
atoms, which constitute the compounds of the general formulas (II-1) to (II-4), may be substituted with isotope atoms thereof).

[0023]

Also the liquid crystal component C can contain compounds selected from the group of compounds represented by the general formulas (III-1) to (III-4):

[0024]

[Chemical Formula 7]



[0025]

(wherein  $W^1$  to  $W^3$ ,  $Z^4$  to  $Z^6$ , ring  $A^3$ , and  $k^3$  to  $k^5$  are as defined above;

$R^2$  and  $R^3$  each independently represents an alkyl or alkoxy group having 1 to 7 carbon atoms or an alkenyl or alkenyloxy group having 2 to 7 carbon atoms, said alkyl, alkoxy, alkenyl or alkenyloxy group can have one F,  $-CH_3$  or  $-CF_3$  as a non-substituent or substituent group, and/or one, or two or more  $-CH_2-$  groups, which are present in said alkyl, alkoxy, alkenyl or alkenyloxy group, may be substituted with  $-O-$ ,  $-CO-$  or  $-COO-$ , while O atoms do not bond with each other directly;

$Y^5$ ,  $Y^6$  and  $Y^7$  each independently represents H, F, Cl,  $-CF_3$ ,  $-OCF_3$ , or  $-CN$ , and  $Y^7$  each independently represents  $-CH_3$ ;

rings  $A^6$  and  $A^7$  each independently represents trans-1,4-cyclohexylene, trans-1,4-cyclohexenylene or trans-1,3-dioxane-2,5-diyl, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene;

one, or two or more hydrogen atoms, which are present in rings  $A^3$ ,  $A^6$  and  $A^7$ , may be substituted with a deuterium atom; and

atoms, which constitute the compounds of the general formulas (III-1) to (III-4), may be substituted with isotope atoms thereof).

[0026]

Furthermore, the present invention provides an active matrix, twisted nematic or super twisted nematic liquid display device using the above nematic liquid crystal



composition, or a light scattering type liquid display device comprising a light modulation layer which contains the above liquid crystal composition and a transparent solid substance.

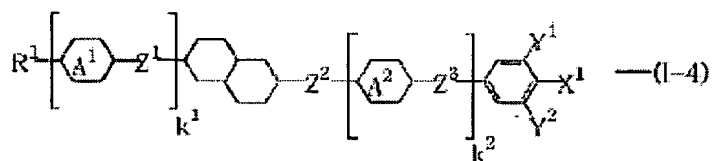
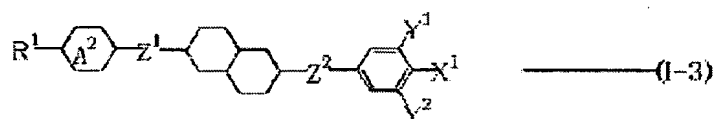
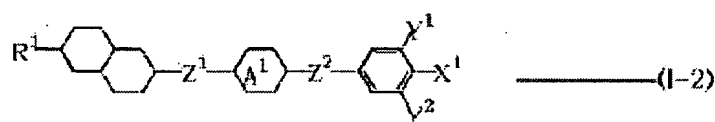
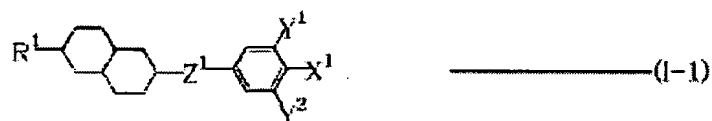
[0027]

To solve the problems described above, the present inventors have found the following means for solving the problems.

1. A nematic liquid crystal composition comprising a liquid crystal component A composed of one, or two or more kinds of compounds represented by one, two, or three or more general formulas selected from the general formulas (I-1) to (I-4):

[0028]

[Chemical Formula 8]



[0029]

(wherein one, or two or more  $-\text{CH}_2-$  groups, which are present in a decahydronaphthalene-2,6-diyl group, may be substituted with  $-\text{CF}_2-$ , one, or two or more  $-\text{CH}_2\text{-CH}_2-$  groups, which are present in said group, may be substituted with  $-\text{CH}_2\text{O}-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{CF}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{CH}=\text{N}-$  or  $-\text{CF}=\text{N}-$ , one, or two or more  $>\text{CH-CH}_2-$  groups, which are present in said group, may be substituted with  $>\text{CH-O}-$ ,  $>\text{C}=\text{CH}-$ ,  $>\text{C}=\text{CF}-$ ,  $>\text{C}=\text{N}-$  or  $>\text{N-CH}_2-$ , and  $>\text{CH-CH}<$  group, which is present in the group, may be independently substituted with  $>\text{CH-CF}<$ ,  $>\text{CF-CF}<$  or  $>\text{C}=\text{C}<$ ;

$\text{R}^1$  each independently represents an alkyl group having 1 to 10 carbon atoms or an alkenyl group having 2 to 10 carbon atoms, said alkyl or alkenyl group can have one F,  $-\text{CH}_3$  or  $-\text{CF}_3$  as a non-substituent or substituent group, and/or one, or two

or more  $-\text{CH}_2-$  groups, which are present in said alkyl or alkenyl group, may be substituted with  $-\text{O}-$ ,  $-\text{CO}-$  or  $-\text{COO}-$ , while O atoms do not bond with each other directly;

$\text{X}^1$  each independently represents F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ ,  $-\text{OCF}_2\text{H}$ ,  $-\text{NCS}$ , or  $-\text{CN}$ ;

$\text{Y}^1$  and  $\text{Y}^2$  each independently represents H, F, Cl,  $-\text{CF}_3$ ,  $-\text{OCF}_3$ , or  $-\text{CN}$ ;

$\text{Z}^1$ ,  $\text{Z}^2$  and  $\text{Z}^3$  each independently represents a single bond,  $-\text{COO}-$ ,  $-\text{OCO}-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{C}\equiv\text{C}-$ ,  $-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_4-$ ,  $-\text{CH}=\text{CH}-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{N}-$ ,  $-\text{CH}=\text{N}-\text{N}=\text{CH}-$ , or  $-\text{N}(\text{O})=\text{N}-$ ;

rings  $\text{A}^1$  and  $\text{A}^2$  each independently represents 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, 3,5-difluoro-1,4-phenylene, pyrimidine-2,5-diyl, trans-1,4-cyclohexylene, trans-1,4-cyclohexenylene, or trans-1,3-dioxane-2,5-diyl;

one, or two or more hydrogen atoms, which are present in a decahydronaphthalene-2,6-diyl group and rings  $\text{A}^1$  and  $\text{A}^2$ , may be substituted with a deuterium atom;

$k^1$  and  $k^2$  each independently represents 0, 1 or 2, and  $k^1 + k^2$  is 2; and

atoms, which constitute the compounds of the general formulas (I-1) to (I-4), may be substituted with isotope atoms thereof); 0 to 99.9% by weight of a liquid crystal component B composed of a compound having a dielectric constant anisotropy of +2 or more as a liquid crystal component excluding the compounds of the general formulas (I-1) to (I-4); and 0 to 85%

by weight of a liquid crystal component C composed of a compound having a dielectric constant anisotropy within a range from -10 to +2; the sum total of said liquid crystal component B and said liquid crystal component C being within a range from 0 to 99.9% by weight.

[0030]

2. A nematic liquid crystal composition described in 1, wherein said liquid crystal component A contains one to twenty kinds of compounds selected from one, two, or three or more general formulas among the above formulas (I-1) to (I-4), the content of said compounds being within a range from 5 to 100% by weight.

[0031]

3. A nematic liquid crystal composition described in 1 or 2, wherein said liquid crystal component A contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (I-ai) to (I-avi), the content of said compounds being within a range from 10 to 100% by weight:

(I-ai) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 7 carbon atoms;

(I-a ii) compound in which  $X^1$  is F, Cl,  $-CF_3$ ,  $-OCF_3$ ,  $-OCF_2H$ , or  $-CN$ ;

(I-a iii) compound in which  $Y^1$  and  $Y^2$  represent is H, F, Cl,  $-CF_3$ , or  $-OCF_3$ ;

(I-a iv) compound in which  $Z^1$ ,  $Z^2$  and  $Z^3$  represent a single bond,  $-(CH_2)_2-$ ,  $-COO-$ , or  $-C\equiv C-$ ;

(I-av) compound in which rings  $A^1$  and  $A^2$  represent trans-1,4-cyclohexylene, 1,4-phenylene, 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene; and

(I-avi) compound in which at least one of rings  $A^1$  and  $A^2$  is substituted with a deuterium atom if the rings  $A^1$  and  $A^2$  represent trans-1,4-cyclohexylene, in the general formulas (I-1) to (I-4).

[0032]

4. A nematic liquid crystal composition described in 1 or 2, wherein said liquid crystal component A contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (I-bi) to (I-bviii), the content of said compounds being within a range from 5 to 100% by weight, if said liquid crystal component A contains the compound of the above general formula (I-1):

(I-bi) compound in which  $R^1$  is an alkenyl group having 2 to 7 carbon atoms;

(I-bii) compound in which one of  $Y^1$  and  $Y^2$  is F, Cl,  $-CF_3$ , or  $-OCF_3$ ;

(I-biii) compound in which  $Z^1$  is  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ , or  $-C\equiv C-$ ;

(I-biv) compound in which a decahydronaphthalene-2,6-diyl group has at least one substituent among substituents  $-CH_2-O-$ ,  $-CH=CH-$ ,  $-CH=CF-$ ,  $-CF=CF-$ ,  $-CH=N-$ ,  $-CF=N-$ ,  $>CH-O-$ ,  $>C=CH-$ ,  $>C=CF-$ ,  $>C=N-$ ,  $>N-CH_2-$ ,  $>CH-CF<$ ,  $>CF-CF<$ , or  $>C=C<$ , in the compounds in which  $X^1$  is  $-CN$ ;

(I-bv) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms;

(I-bvi) compound in which one of  $Y^1$  and  $Y^2$  is H, F, Cl,  $-CF_3$ , or  $-OCF_3$ ;

(I-bvii) compound in which  $Z^1$  is a single bond,  $-(CH_2)_2-$ , or  $-C\equiv C-$ ;

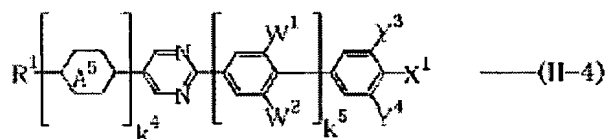
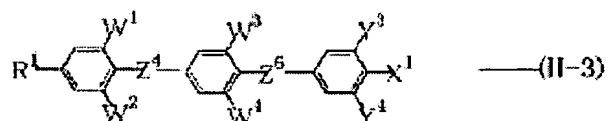
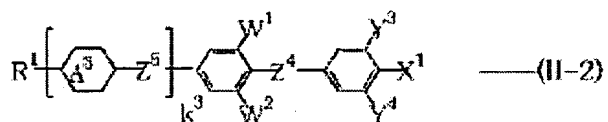
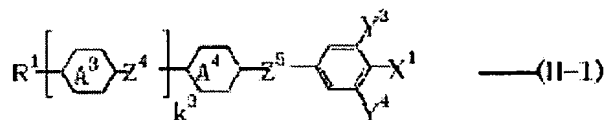
(I-bviii) compound in which a decahydronaphthalene-2,6-diyl group has at least one substituent among substituents  $-CH_2-O-$ ,  $-CH=CH-$ ,  $-CH=CF-$ ,  $-CF=CF-$ ,  $-CH=N-$ ,  $-CF=N-$ ,  $>CH-O-$ ,  $>C=CH-$ ,  $>C=CF-$ ,  $>C=N-$ ,  $>N-CH_2-$ ,  $>CH-CF<$ ,  $>CF-CF$ , or  $>C=C<$ , in the compounds in which  $X^1$  is F, Cl,  $-CF_3$ , or  $-OCF_3$ .

[0033]

5. A nematic liquid crystal composition described in 1, 2, 3 or 4, wherein said liquid crystal component B contains one, or two or more kinds of compounds selected from the group of compounds represented by the general formulas (II-1) to (II-4):

[0034]

[Chemical Formula 9]



[0035]

(wherein  $R^1$  and  $X^1$  are as defined in claim 1;

$Y^3$  and  $Y^4$  each independently represents H, F, Cl, or -  
OCF<sub>3</sub>,

$W^1$ ,  $W^2$ ,  $W^3$  and  $W^4$  each independently represents H, F, or  
Cl;

$Z^4$ ,  $Z^5$  and  $Z^6$  each independently represents a single  
bond, -COO-, -OCO-, -CH<sub>2</sub>O-, -OCH<sub>2</sub>-, -(CH<sub>2</sub>)<sub>2</sub>-, -(CH<sub>2</sub>)<sub>4</sub>-,  
-CH=CH-(CH<sub>2</sub>)<sub>2</sub>-, -(CH<sub>2</sub>)<sub>2</sub>-CH=CH-, -CH=N-, -CH=N-N=CH-, or  
-N(O)=N-, and  $Z^4$  and  $Z^6$  each independently represents -  
CH=CH-, -CF=CF-, or C≡C-;

rings  $A^3$ ,  $A^4$  and  $A^5$  each independently represents trans-  
1,4-cyclohexylene, trans-1,4-cyclohexenylene, or trans-1,3-  
dioxane-2,5-diyl, and the ring  $A^5$  may also be 1,4-phenylene,

2- or 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene, and one, or two or more hydrogen atoms, which are present in rings  $A^3$ ,  $A^4$  and  $A^5$ , may be substituted with a deuterium atom;

$k^3$ ,  $k^4$  and  $k^5$  each independently represents 0 or 1, and  $k^4 + k^5$  is 0 or 1; and

atoms, which constitute the compounds of the general formulas (II-1) to (II-4), may be substituted with isotope atoms thereof).

[0036]

6. A nematic liquid crystal composition described in 5, wherein said liquid crystal component B contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (II-ai) to (II-axii), the content of said compounds being within a range from 10 to 100% by weight:

(II-ai) compounds in which  $R^1$  is an alkenyl group having 2 to 5 carbon atoms, in the general formulas (II-1) to (II-4);

(II-a ii) compounds in which  $X^1$  is F, Cl, or  $-OCF_3$ , in the general formulas (II-1) to (II-4);

(II-a iii) compounds in which  $Z^5$  is  $-(CH_2)_2-$  or  $-(CH_2)_4-$ , in the general formula (II-1);

(II-a iv) compound in which  $k^3$  is 1, in the general formula (II-1);

(II-a v) compound in which at least one of  $Y^3$ ,  $Y^4$ ,  $W^1$  and  $W^2$  is F, in the general formula (II-2);

(II-a vi) compound in which  $k^3$  is 1 and  $Z^4$  is  $-C\equiv C-$ , in the general formula (II-2);



(II-avii) compound in which  $Z^5$  is a single bond or  $-(CH_2)_2-$  and  $Z^4$  is  $-COO-$ , in the general formula (II-2);

(II-aviii) compound in which at least one of  $Y^3$ ,  $Y^4$ ,  $W^1$ ,  $W^2$ ,  $W^3$  and  $W^4$  is F, in the general formula (II-3);

(II-aix) compound in which  $Z^6$  is  $-C\equiv C-$ , in the general formula (II-3);

(II-ax) compound in which  $Z^4$  is a single bond or  $-C\equiv C-$  and  $Z^6$  is  $-COO-$ , in the general formula (II-3);

(II-axi) compound represented by the general formula (II-4);

and

(II-axii) compound in which at least one of rings  $A^3$ ,  $A^4$  and  $A^5$  is substituted with a deuterium atom if the rings  $A^3$ ,  $A^4$  and  $A^5$  represent trans-1,4-cyclohexylene, in the general formulas (II-1), (II-2) and (II-4).

[0037]

7. A nematic liquid crystal composition described in 5, wherein said liquid crystal component B contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (II-bi) to (II-bviii), the content of said compounds being within a range from 10 to 100% by weight:

(II-bi) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $X^1$  is  $-CN$ , in the general formula (II-1);

(II-bii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $X^1$  is F or  $-CN$ , and  $Y^3$  and  $Y^4$  each independently represents H or F, in the general

formula (II-1);

(II-biii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 0,  $X^1$  is  $-CN$ , and  $Y^3, Y^4, W^1$  and  $W^2$  represent H or F, in the general formula (II-2);

(II-biv) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^5$  is a single bond,  $-(CH_2)_2-$ , or  $-COO-$ ,  $Z^4$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ ,  $X^1$  is F or  $-CN$ , and  $Y^3, Y^4, W^1$  and  $W^2$  represent H or F, in the general formula (II-2);

(II-bv) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, and one of  $Z^4$  and  $Z^6$  is a single bond and other one is a single bond,  $-COO-$ , or  $-C\equiv C-$ , in the general formula (II-3);

(II-bvi) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, and  $Y^3, Y^4, W^1, W^2, W^3$  and  $W^4$  represent H or F, in the general formula (II-3);

(II-bvii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 7 carbon atoms, and  $k^4+k^5=0$ , in the general formula (II-4); and

(II-bviii) compounds in which at least one hydrogen atom of rings  $A^3$  and  $A^4$  is substituted with a deuterium atom if the rings  $A^3$  and  $A^4$  represent trans-1,4-cyclohexylene, in the general formulas (II-1) to (II-2).

[0038]

8. A nematic liquid crystal composition described in 5, wherein said liquid crystal component B contains one to twenty kinds of compounds selected from one, two, or three or more

sub-groups among the following sub-groups (II-ci) to (II-civ), the content of said compounds being within a range from 10 to 100% by weight:

(II-ci) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1, one of  $Z^4$  and  $Z^5$  is a single bond and other one is a single bond,  $-COO-$ ,  $-(CH_2)_2-$ , or  $-(CH_2)_4$ ,  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$ , and one, or two or more of  $Y^3$  and  $Y^4$  represent F, in the general formula (II-1);

(II-cii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^5$  is a single bond,  $-(CH_2)_2-$ , or  $-COO-$ ,  $Z^4$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ ,  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$ , one, or two or more of  $Y^3$  and  $Y^4$  represent F, and  $W^1$  and  $W^2$  represent H or F, in the general formula (II-2);

(II-ciii) compound in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, one of  $Z^4$  and  $Z^6$  is a single bond and the other one is a single bond,  $-COO-$ , or  $-C\equiv C-$ ,  $X^1$  is F, Cl,  $-CF_3$ ,  $-OCF_3$ , or  $-OCF_2H$ , one, or two or more of  $Y^3$  and  $Y^4$  represent F, and  $W^1$ ,  $W^2$ ,  $W^3$  and  $W^4$  represent H or at least one of them is F, in the general formula (II-3); and

(II-civ) compounds in which at least three hydrogen atoms of rings  $A^3$  and  $A^4$  are substituted with a deuterium atom if the rings  $A^3$  and  $A^4$  represent trans-1,4-cyclohexylene, in the general formulas (II-1) and (II-2).

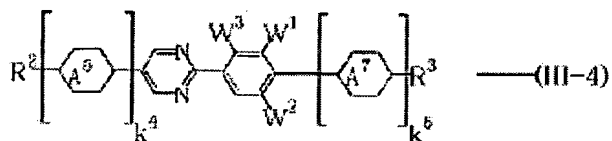
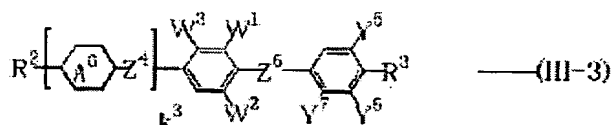
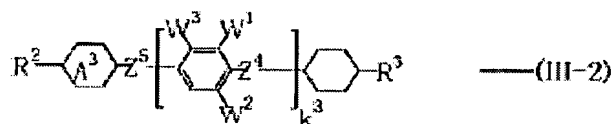
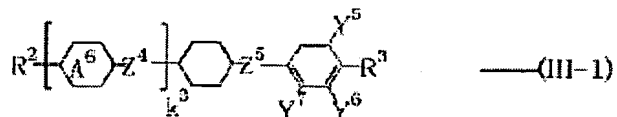
[0039]

9. A nematic liquid crystal composition described in 1, 2, 3, 4, 5, 6, 7 or 8, wherein said liquid crystal component C

contains compounds selected from the group of compounds represented by the general formulas (III-1) to (III-4):

[0040]

[Chemical Formula 10]



[0041]

(wherein  $W^1$  to  $W^3$ ,  $Z^4$  to  $Z^6$ , ring  $A^3$ , and  $k^3$  to  $k^5$  are as defined in claims 1 and 5;

$R^2$  and  $R^3$  each independently represents an alkyl or alkoxy group having 1 to 7 carbon atoms or an alkenyl or alkenyloxy group having 2 to 7 carbon atoms, said alkyl, alkoxy, alkenyl or alkenyloxy group can have one F,  $-\text{CH}_3$  or  $-\text{CF}_3$  as a non-substituent or substituent group, and/or one, or two or more  $-\text{CH}_2-$  groups, which are present in said alkyl, alkoxy, alkenyl or alkenyloxy group, may be substituted with  $-\text{O}-$ ,  $-\text{CO}-$  or  $-\text{COO}-$ , while O atoms do not bond with each other directly;

$Y^5$ ,  $Y^6$  and  $Y^7$  each independently represents H, F, Cl,

-CF<sub>3</sub>, -OCF<sub>3</sub>, or -CN, and Y<sup>7</sup> each independently represents -CH<sub>3</sub>;

rings A<sup>6</sup> and A<sup>7</sup> each independently represents trans-1,4-cyclohexylene, trans-1,4-cyclohexenylene or trans-1,3-dioxane-2,5-diyl, 1,4-phenylene, 2- or 3-fluoro-1,4-phenylene, 2,3-difluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene;

one, or two or more hydrogen atoms, which are present in rings A<sup>3</sup>, A<sup>6</sup> and A<sup>7</sup>, may be substituted with a deuterium atom; and

atoms, which constitute the compounds of the general formulas (III-1) to (III-4), may be substituted with isotope atoms thereof).

[0042]

10. A nematic liquid crystal composition described in 9, wherein said liquid crystal component C contains one, or two or more kinds of compounds selected from compounds represented by the general formula (III-1), and/or compounds represented by the general formula (III-2), and/or compounds represented by the general formula (III-3), the content of said compounds being within a range from 10 to 100% by weight.

[0043]

11. A nematic liquid crystal composition described in 9, wherein said liquid crystal component C contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (III-ai) to (III-axii), the content of said compounds being within a range from 10 to 100% by weight:

(III-ai) compounds in which R<sup>2</sup> is an alkenyl group having 2 to

5 carbon atoms, in the general formulas (III-1) to (III-4);  
 (III-aii) compounds in which  $R^3$  is a straight-chain alkenyl or alkenyloxy group having 2 to 7 carbon atoms, in the general formulas (III-1) to (III-4);

(III-aiii) compounds in which  $k^3$  is 0 and  $Z^5$  is a single bond or  $-(CH_2)_2-$ , in the general formula (III-1);

(III-aiv) compound in which  $k^3$  is 1, in the general formula (III-1);

(III-av) compound represented by the general formula (III-2);

(III-avi) compound in which at least one of  $Y^5$ ,  $Y^6$ ,  $W^1$ ,  $W^2$  and  $W^3$  is F, in the general formula (III-3);

(III-avii) compound in which  $Y^7$  is F or  $-CH_3$ , in the general formula (III-3);

(III-aviii) compound in which  $k^3$  is 0 and  $Z^6$  is a single bond, in the general formula (III-3);

(III-aix) compound in which  $k^3$  is 1,  $Z^4$  is a single bond,  $-OCO-$ ,  $-CH_2O-$ ,  $-OCH_2-$ ,  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ ,

$-CH=CH-(CH_2)_2-$ ,  $-(CH_2)_2-CH=CH-$ ,  $-CH=N-$ ,  $-CH=N-N=CH-$ ,  $-N(O)=N-$ ,  $-CH=CH-$ , or  $-CF=CF-$ , in the general formula (III-3);

(III-ax) compound in which  $Z^4$  is  $-COO-$  or  $-C\equiv C-$  and  $Z^6$  is  $-OCO-$ ,  $-CH_2O-$ ,  $-OCH_2-$ ,  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ ,

$-CH=CH-(CH_2)_2-$ ,  $-(CH_2)_2-CH=CH-$ ,  $-CH=N-$ ,

$-CH=N-N=CH-$ ,  $-N(O)=N-$ ,  $-CH=CH-$ ,  $-CF=CF-$ , or  $-C\equiv C-$ , in the general formula (III-3);

(III-axi) compound represented by the general formula (III-4);  
 and

(III-axii) compounds in which at least one hydrogen atom of rings  $A^3$ ,  $A^6$  and  $A^7$  is substituted with a deuterium atom if the rings  $A^3$ ,  $A^6$  and  $A^7$  represent trans-1,4-cyclohexylene, in the general formulas (III-1) to (III-4).

[0044]

12. A nematic liquid crystal composition described in 9, wherein said liquid crystal component C contains one to twenty kinds of compounds selected from one, two, or three or more sub-groups among the following sub-groups (III-bi) to (III-bix), the content of said compounds being within a range from 10 to 100% by weight:

(III-bi) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $Z^5$  is a single bond,  $-\text{COO}-$ , or  $-(\text{CH}_2)_2$ , in the general formula (III-1);

(III-bii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1, the ring  $A^6$  is trans-1,4-cyclohexylene, and one of  $Z^4$  and  $Z^5$  is a single bond and other one is a single bond,  $-\text{COO}-$ , or a  $-(\text{CH}_2)_2-$ , in the general formula (III-1);

(III-biii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or

an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, the ring  $A^3$  is trans-1,4-cyclohexylene or trans-1,4-cyclohexenylene,  $k^3$  is 0, and  $Z^5$  is a single bond,  $-COO-$ , or  $-(CH_2)_2-$ , in the general formula (III-2);

(III-biv) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, the ring  $A^3$  is trans-1,4-cyclohexylene or trans-1,4-cyclohexenylene,  $k^3$  is 1, and one of  $Z^4$  and  $Z^5$  is a single bond, in the general formula (III-2);

(III-bv) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $Z^6$  is a single bond,  $-C\equiv C-$ , or  $-CH=N-N=CH-$ , in the general formula (III-3);

(III-bvi) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^4$  is a single bond,  $-(CH_2)_2-$ ,  $-COO-$ , or  $-C\equiv C-$ , and  $Z^6$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ , in the general formula (III-3);

(III-bvii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or



an alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1, one of  $Z^4$  and  $Z^6$  is a single bond and other one is a single bond or  $-C\equiv C-$ , and at least one of  $W^1$  and  $W^2$  is F, in the general formula (III-3);

(III-bviii) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, and any one of  $Y^6$  and  $Y^7$  is substituted with F or  $-CH_3$ , in the general formula (III-3); and

(III-bix) compound in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkyloxy group having 1 to 5 carbon atoms, or an alkenyl or alkenyloxy group having 2 to 5 carbon atoms, and  $k^4+k^5=0$ , in the general formula (III-4).

[0045]

13. A nematic liquid crystal composition described in any one of 1 to 12, wherein said liquid crystal composition contains one, or two or more kinds of core-structure compounds which have four six-membered rings and a liquid crystal phase-isotropic liquid phase transition temperature of 100°C or higher.

14. A nematic liquid crystal composition described in any one of 1 to 13, wherein said liquid crystal composition has a dielectric constant anisotropy within a range from 2 to 40, a birefringent index within a range from 0.02 to 0.40, a nematic phase-isotropic liquid phase transfer temperature within a

range from 50 to 180°C or higher, and a crystal phase-, smectic phase- or glass phase-nematic phase transfer temperature within a range from -200 to 0°C.

[0047]

15. A nematic liquid crystal composition described in any one of 1 to 14, wherein said liquid crystal composition contains a compound having an optically active group capable of securing an induced helical pitch within a range from 0.5 to 1000  $\mu\text{m}$ .

[0048]

16. An active matrix, twisted nematic or super twisted nematic liquid display device using the nematic liquid crystal composition described in 15.

[0049]

17. A light scattering type liquid display device comprising a light modulation layer which contains the liquid crystal composition described in any one of 1 to 15 and a transparent solid substance.

[0050]

18. A light scattering type liquid display device described in 17, wherein said liquid crystal composition formed a continuous layer in said light modulation layer and said transparent solid substance formed a uniform three-dimensional network in said continuous layer.

[Embodiments of the Invention]

[0051]

One embodiment of the present invention will be described hereinafter.

[0052]

The symbols  $R^1$ ,  $X^1$ ,  $W^1$  to  $W^3$ ,  $Z^4$  to  $Z^6$ ,  $A^3$ , and  $K^3$  to  $K^5$  of the present invention, which will be described hereinafter, may be the same or different in the general formulas (I-1) to (I-4), (II-1) to (II-4) and (III-1) to (III-4).

[0053]

The liquid crystal composition of the present invention contains, as an essential component, a liquid crystal component A composed of compounds of the general formulas (I-1) to (I-4). The compounds represented by the general formulas (I-1) to (I-4) are characterized by a molecular structure having, as a partial structure, non-substituted or substituted decahydronaphthalene-2,6-diyl group. The liquid crystal component A having this feature has the effects that the response characteristics are maintained because of the comparatively good nematic phase-isotropic liquid phase transition temperature, or that the driving voltage is reduced without deteriorating the response characteristics, when mixing the liquid crystal component A with a liquid crystal compound or composition, and has excellent characteristics which are not found in a conventional liquid crystal compounds having a reduced driving voltage. The present inventors have found that this effect can be exerted when the liquid crystal composition contains a liquid crystal component A composed of compounds of the general formulas (I-1) to (I-4), 0 to 99.9% by weight of a liquid crystal component B composed of a compound having a dielectric constant anisotropy of +2 or more

and 0 to 85% by weight of a liquid crystal component C composed of a compound having a dielectric constant anisotropy within a range from -10 to +2, the sum total of the liquid crystal component B and the liquid crystal component C being within a range from 0 to 99.9% by weight. The liquid crystal component A noticeably reduces the solid phase- or smectic phase-nematic phase transition temperature and lengthens the storage time at low temperature, thereby making it possible to widen the display temperature range, when mixing the liquid crystal component A with liquid crystal materials of the liquid crystal component B and the liquid crystal component C.

[0054]

In the present invention, the liquid crystal component A can be composed of compounds selected from one, two, three or four general formulas among the general formulas (I-1) to (I-4). The liquid crystal component A may be composed of each of the compounds of the general formula (I-1) alone, or may be composed of a combination with compounds selected from one, two or three general formulas among the general formulas (I-2) to (I-4). In this case, it is preferred to use it in combination with compounds selected from compounds of the general formula (I-2) and/or (I-3). The liquid crystal component A may be composed of each of the compounds of the general formula (I-2) or (I-3) alone, or may be composed of a combination with compounds selected from among the other general formulas. In this case, it is preferred to use it in combination with compounds selected from compounds of the

general formula (I-1). The liquid crystal component A may be composed of each of the compounds of the general formula (I-4) alone because the temperature range of the nematic phase can be adjusted using a small amount of these compounds, or may be composed of a combination of it with compounds selected from one, two or three general formulas among the general formulas (I-1) to (I-3). The liquid crystal component A thus composed can contain one to forty kinds of compounds selected from compounds of the general formulas (I-1) to (I-4), but preferably contains one to twenty kinds of compounds. The present inventors have found that the liquid crystal component A is preferable in order to obtain the effects of the present invention.

[0055]

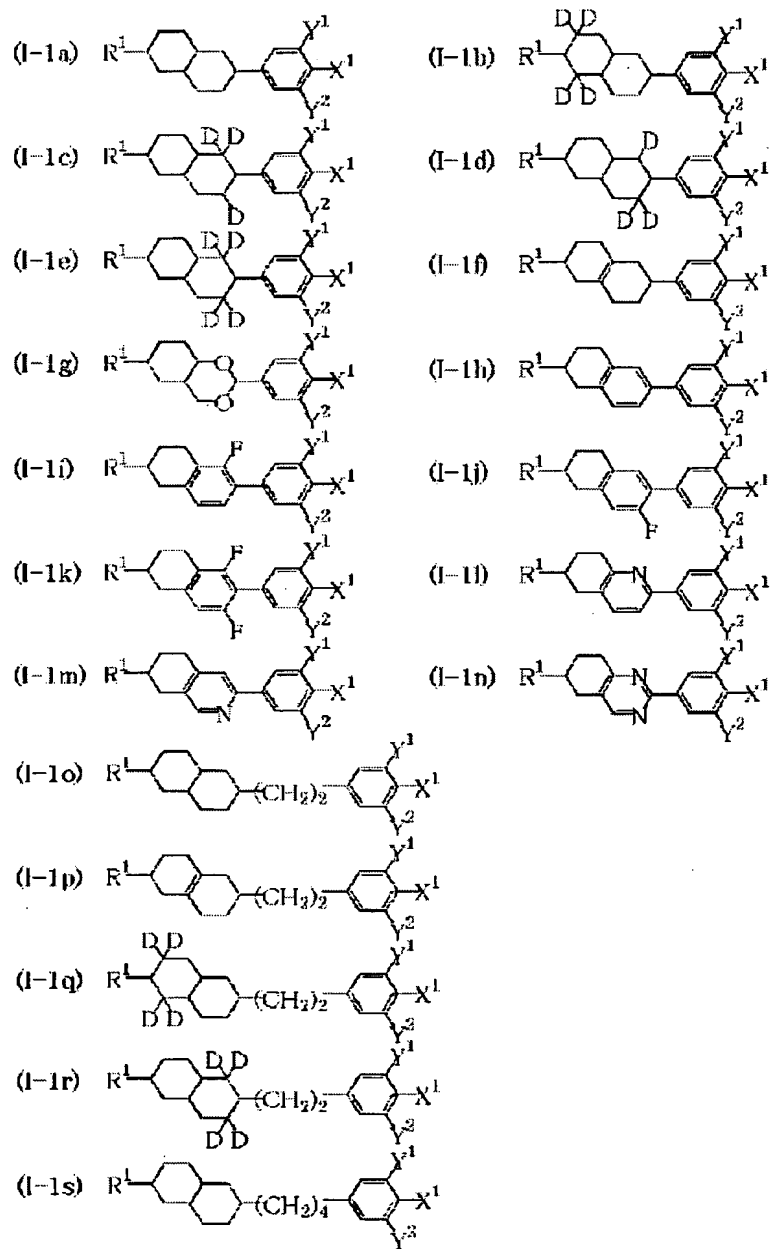
In the present invention, if a nematic liquid crystal composition which does not contain the liquid crystal component B and the liquid crystal component C and is composed only of the liquid crystal component A, the liquid crystal component A contains two to forty kinds of compounds selected from the general formulas (I-1) to (I-4).

[0056]

In view of the above, more preferred embodiments of basic structures of the compounds represented by the general formulas (I-1) to (I-4) are compounds represented by the general formulas (I-1a) to (I-4ap).

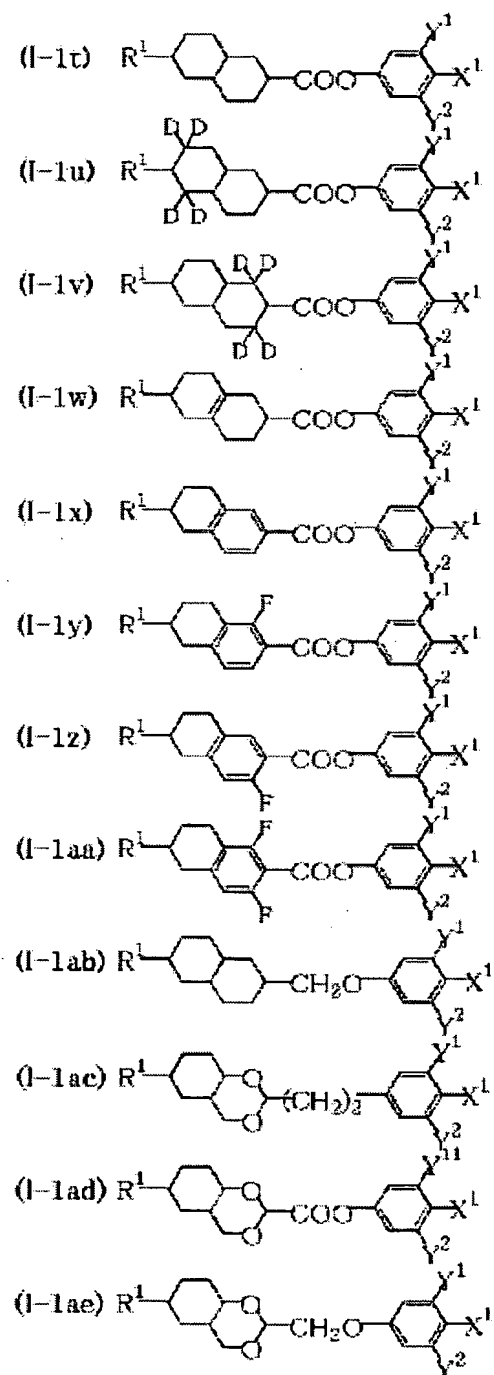
[0057]

[Chemical Formula 11]



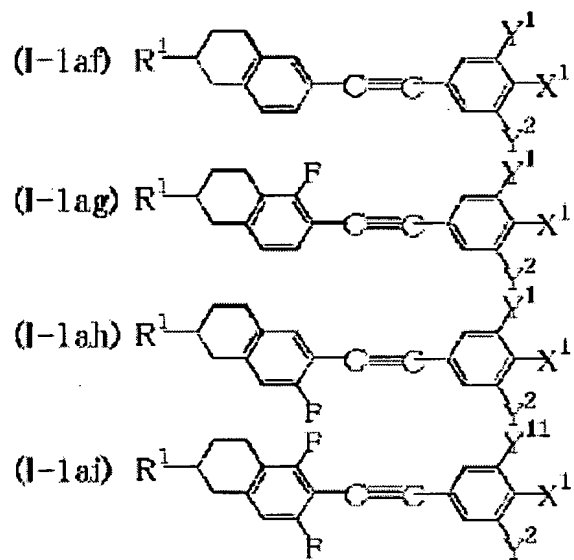
[0058]

[Chemical Formula 12]



[0059]

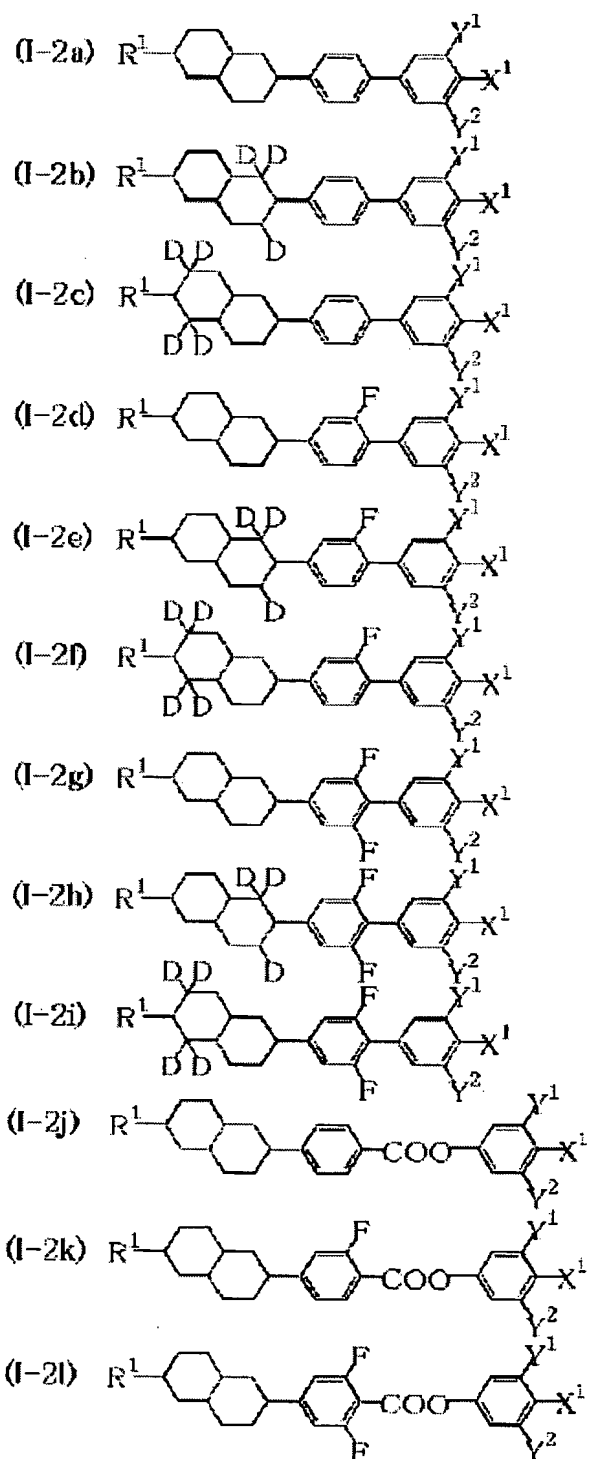
[Chemical Formula 13]





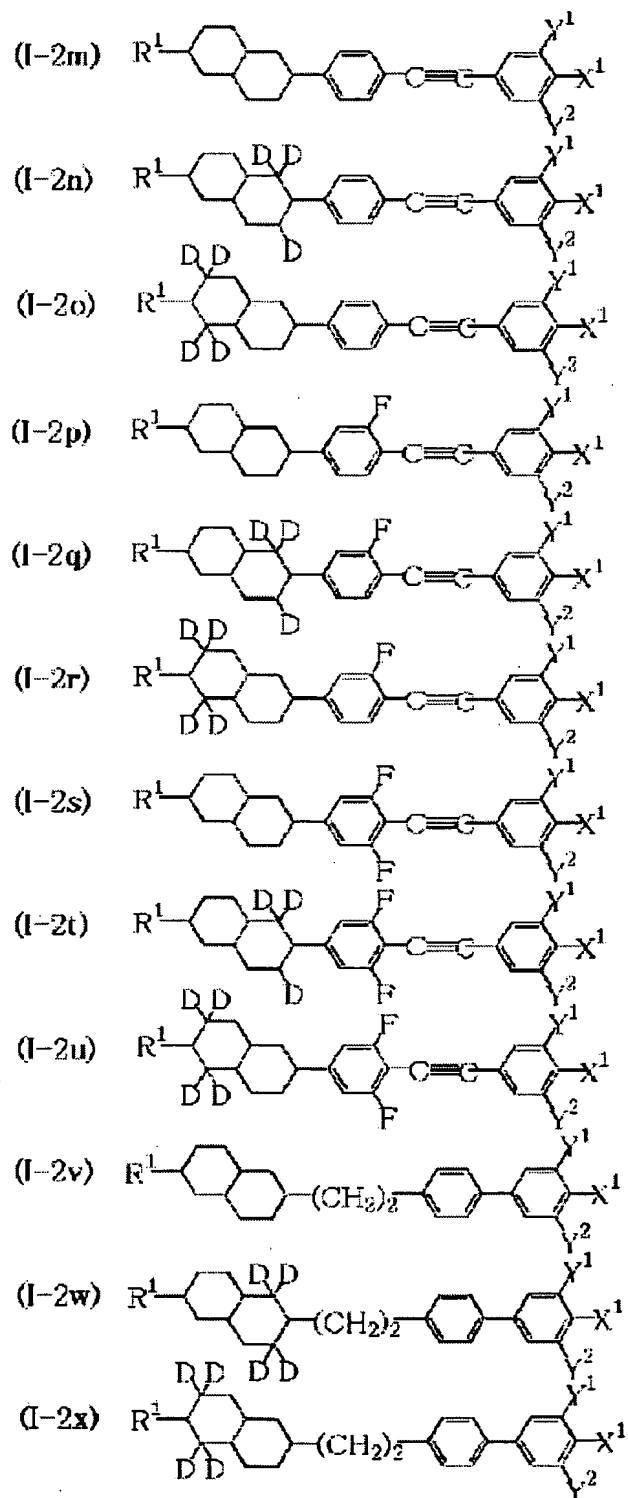
[0060]

[Chemical Formula 14]



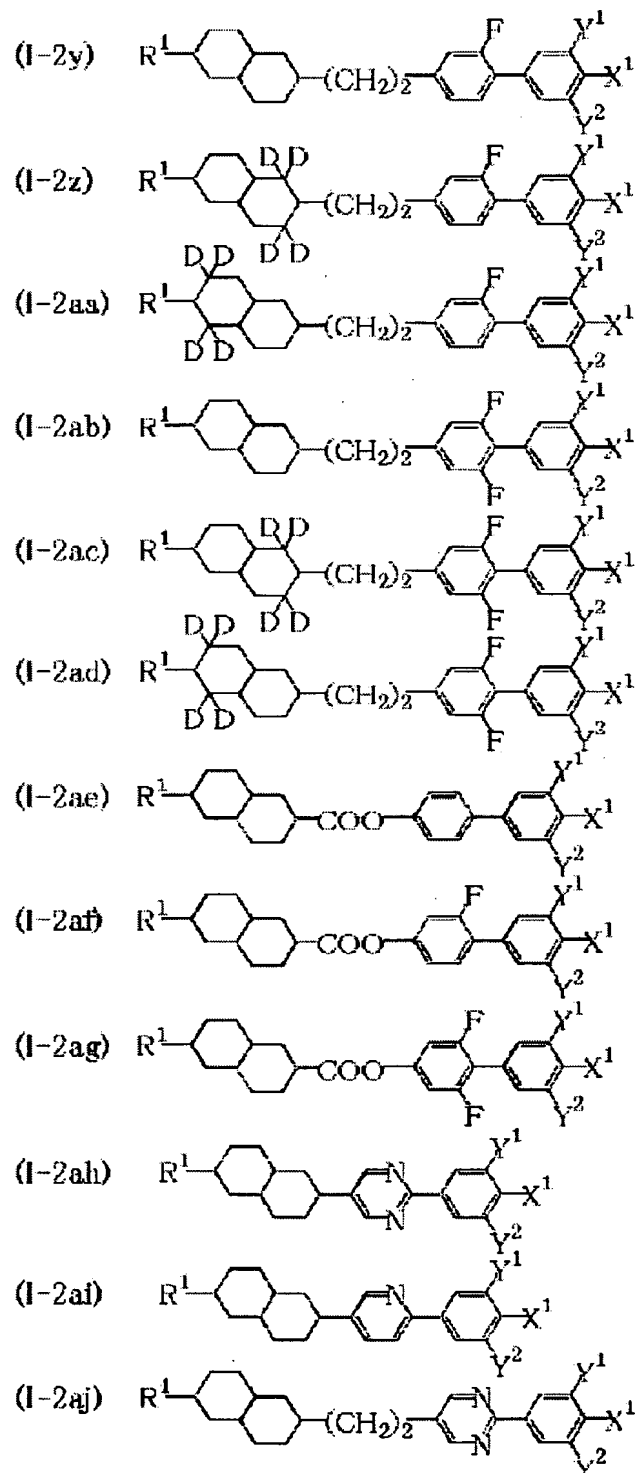
[0061]

[Chemical Formula 15]



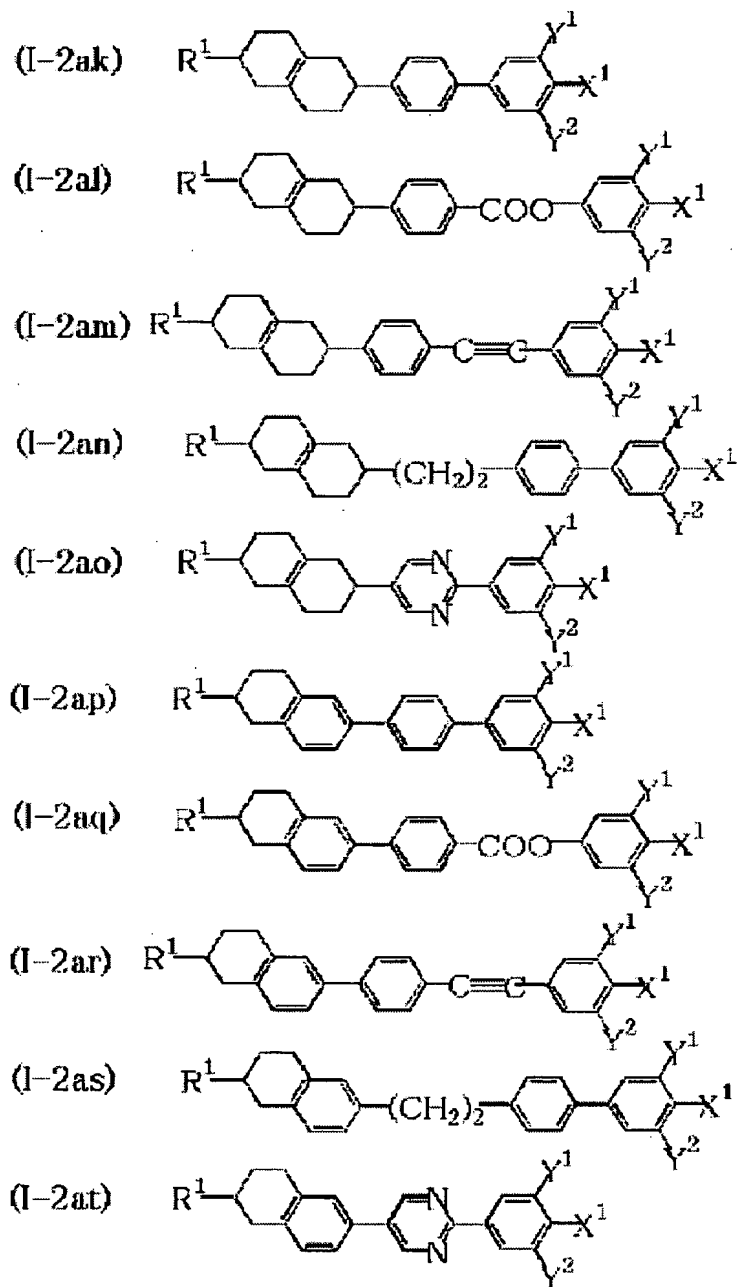
[0062]

[Chemical Formula 16]



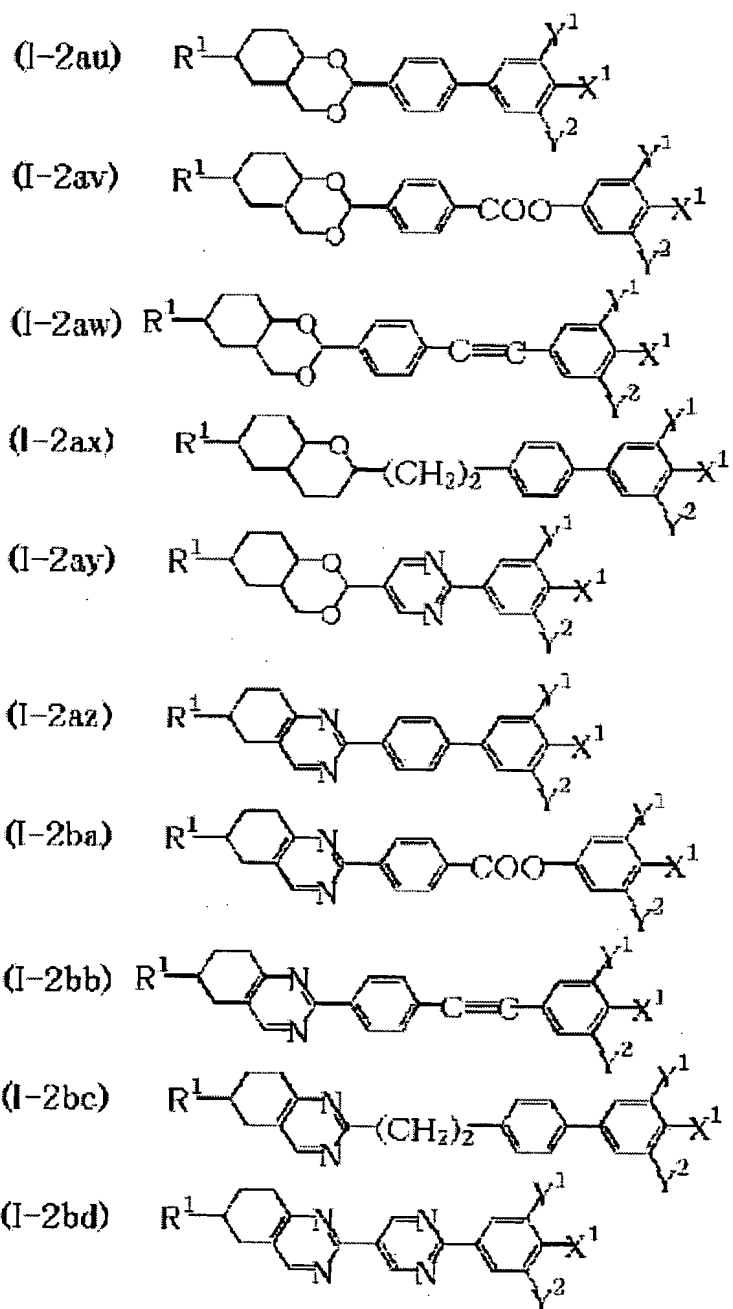
[0063]

[Chemical Formula 17]



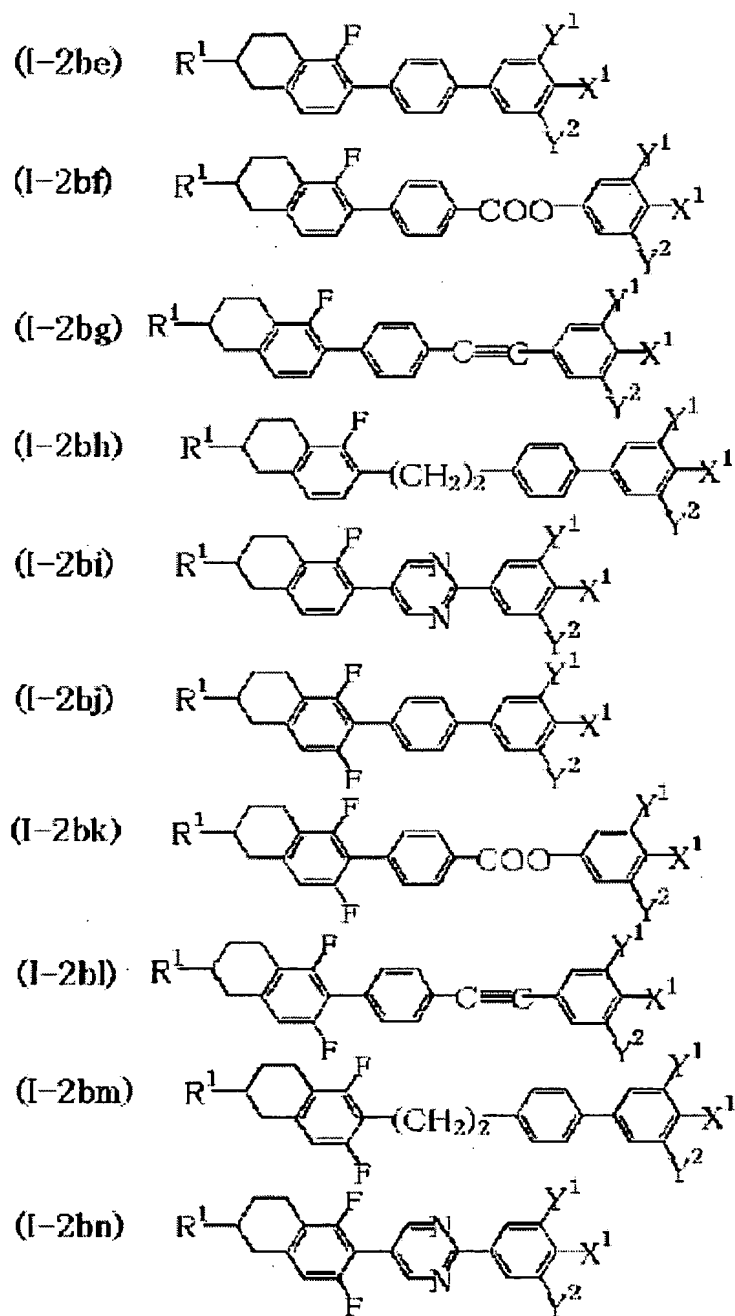
[0064]

[Chemical Formula 18]



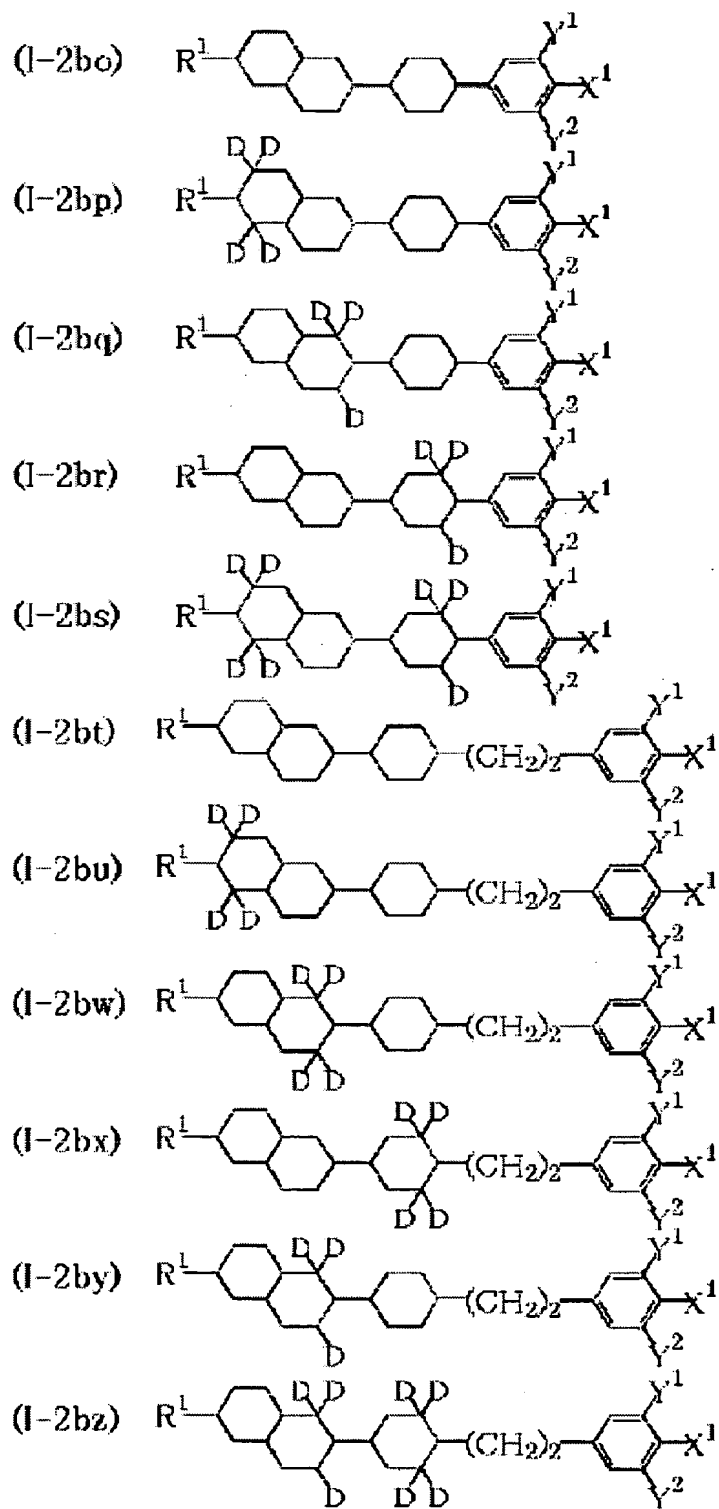
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[Chemical Formula 19]



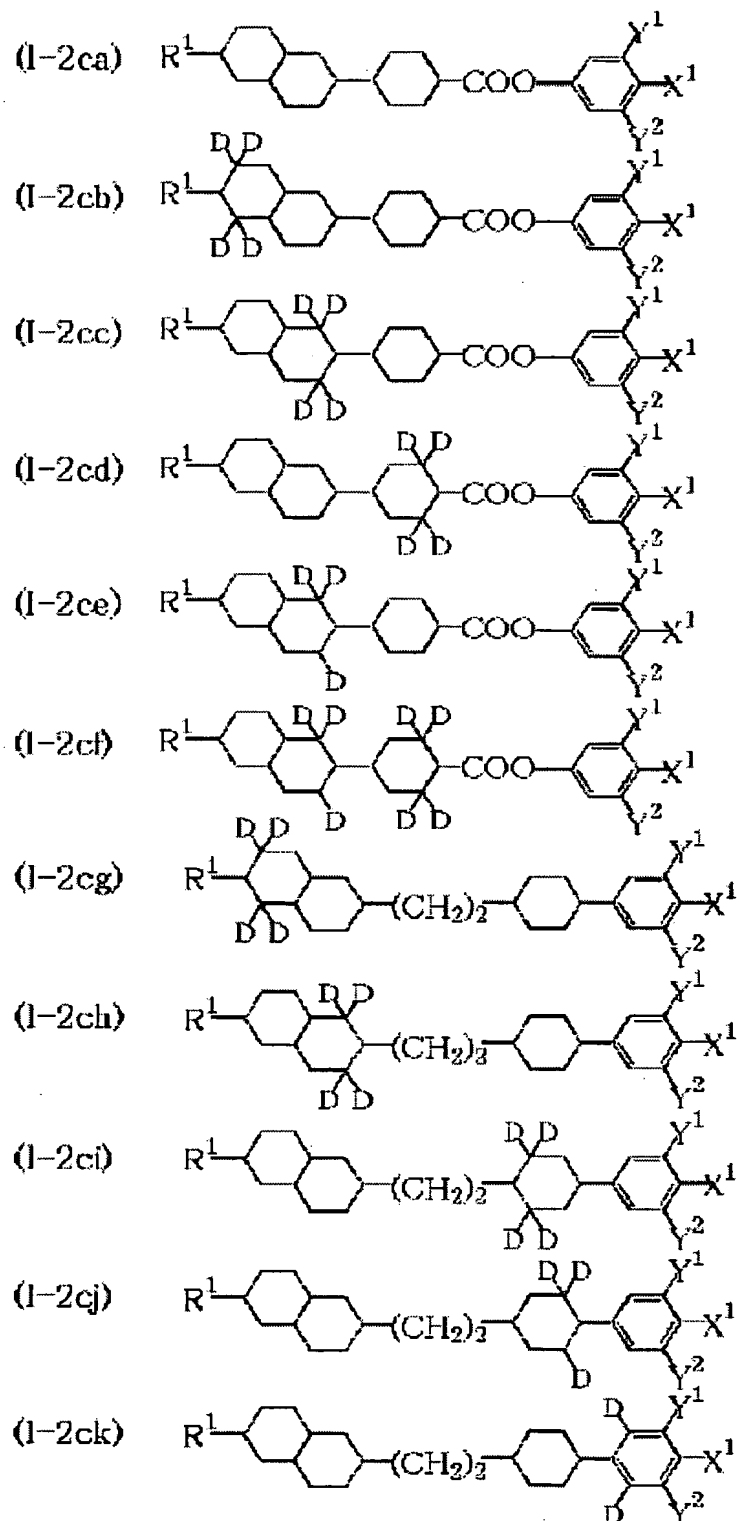
[0066]

[Chemical Formula 20]



[0067]

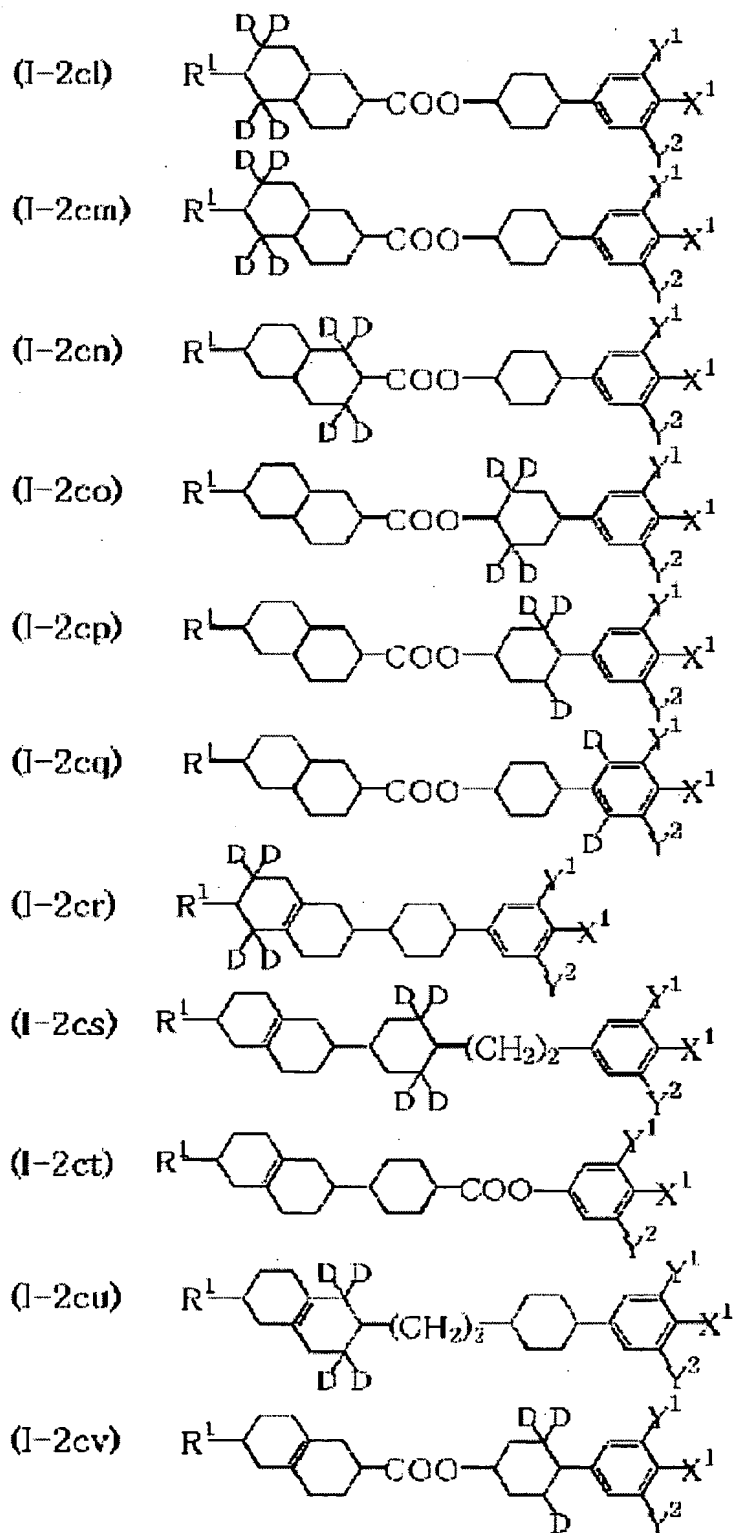
[Chemical Formula 21]





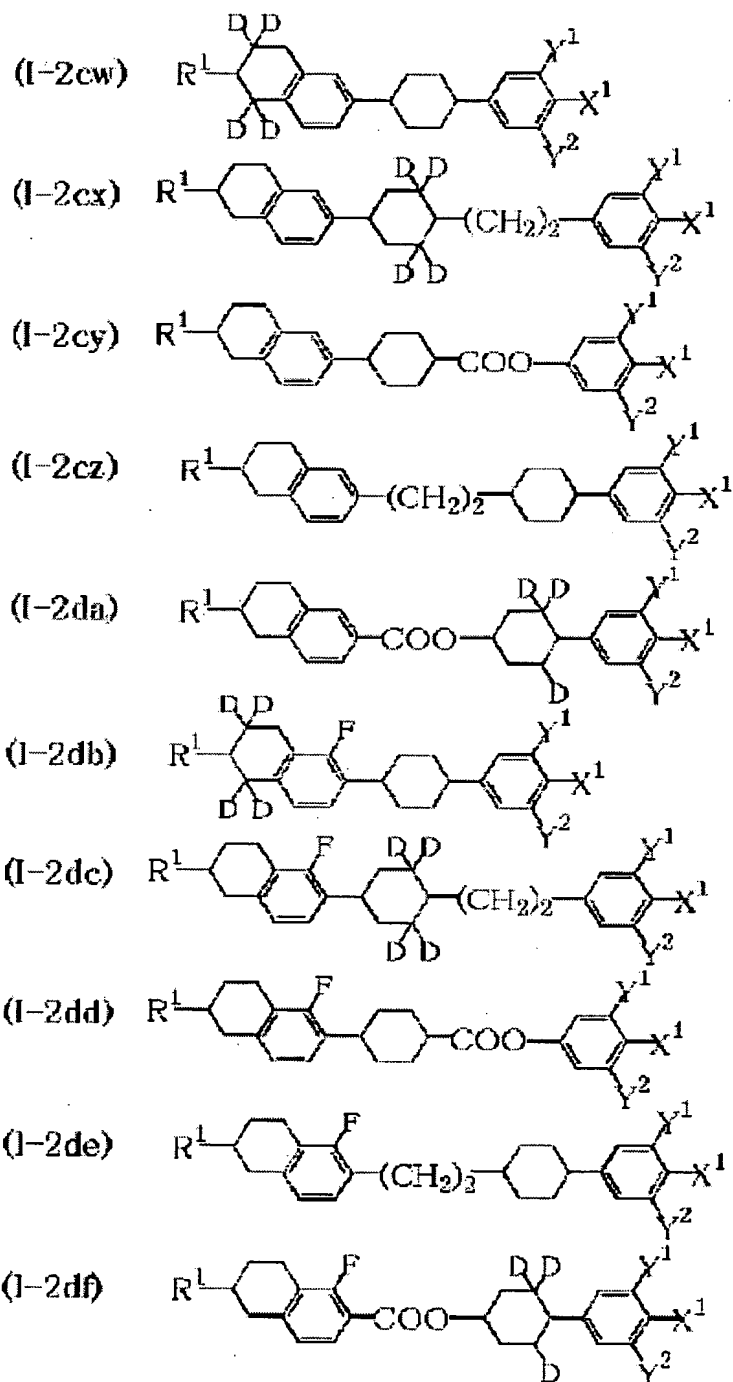
[0068]

[Chemical Formula 22]



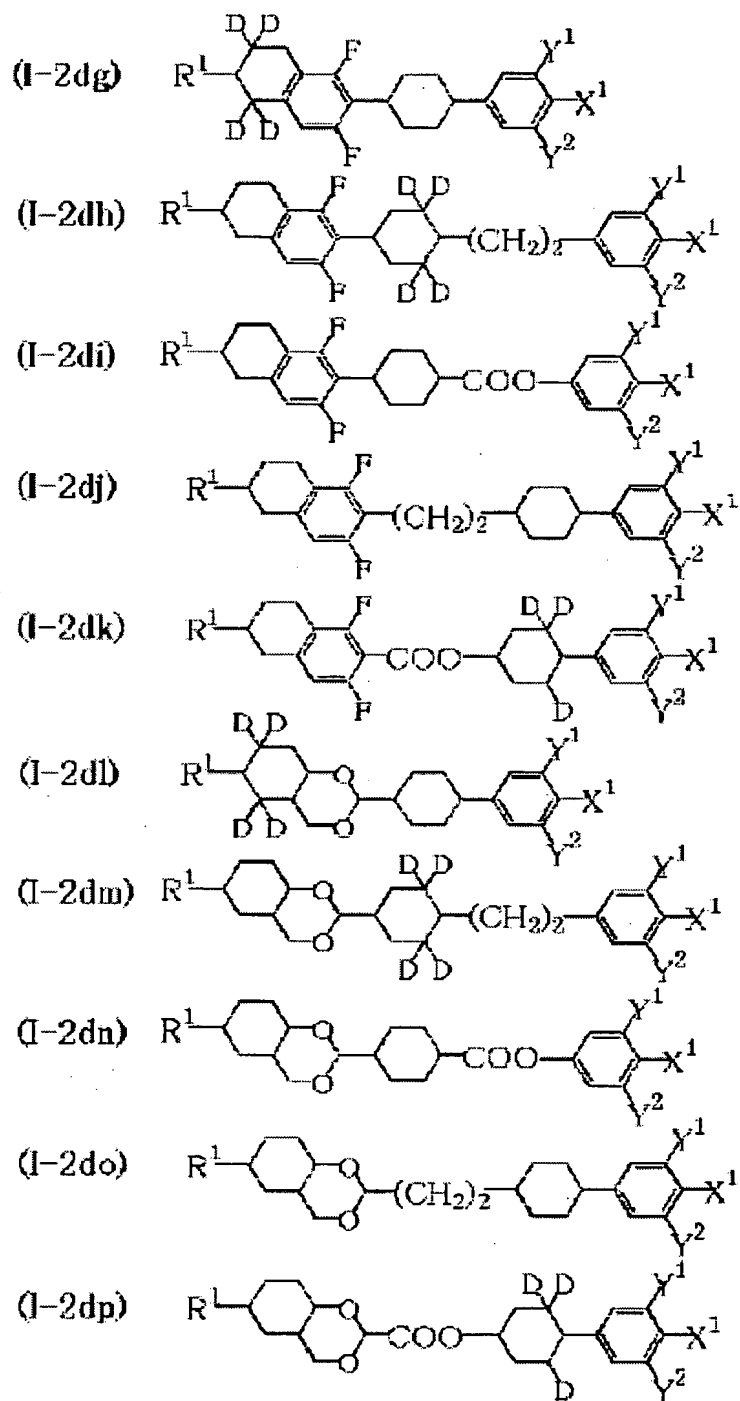
[0069]

[Chemical Formula 23]



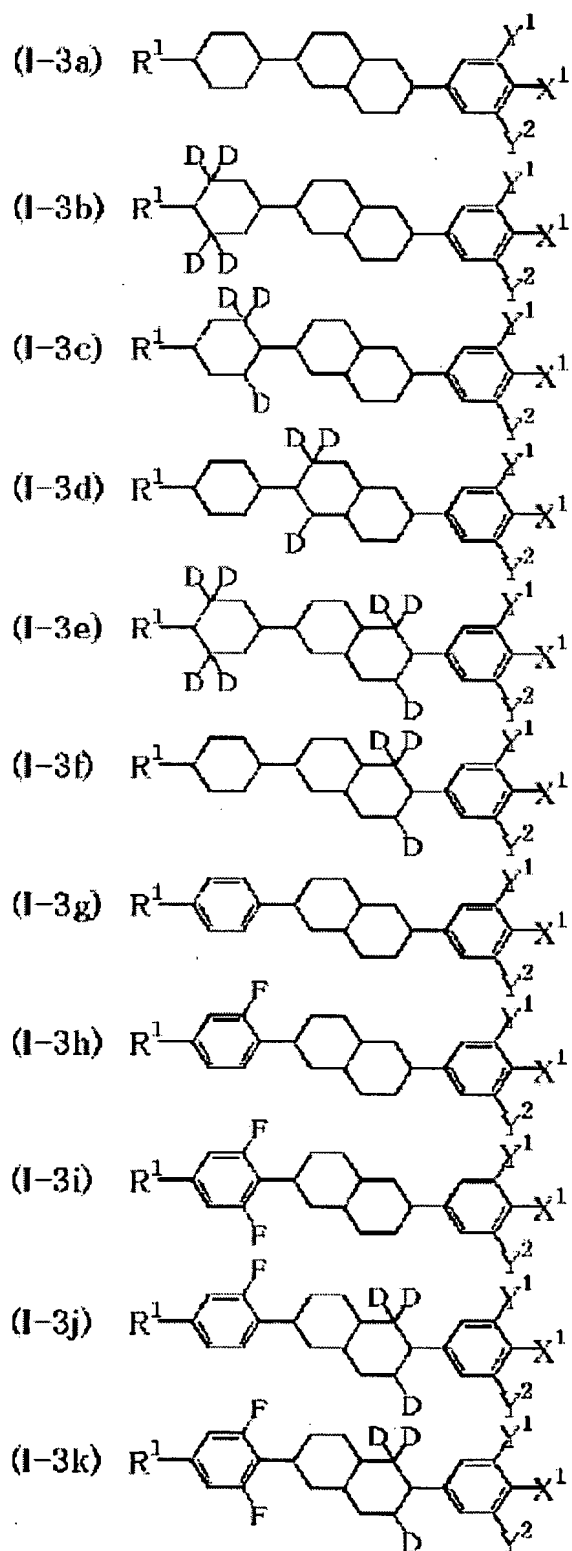
[0070]

[Chemical Formula 24]



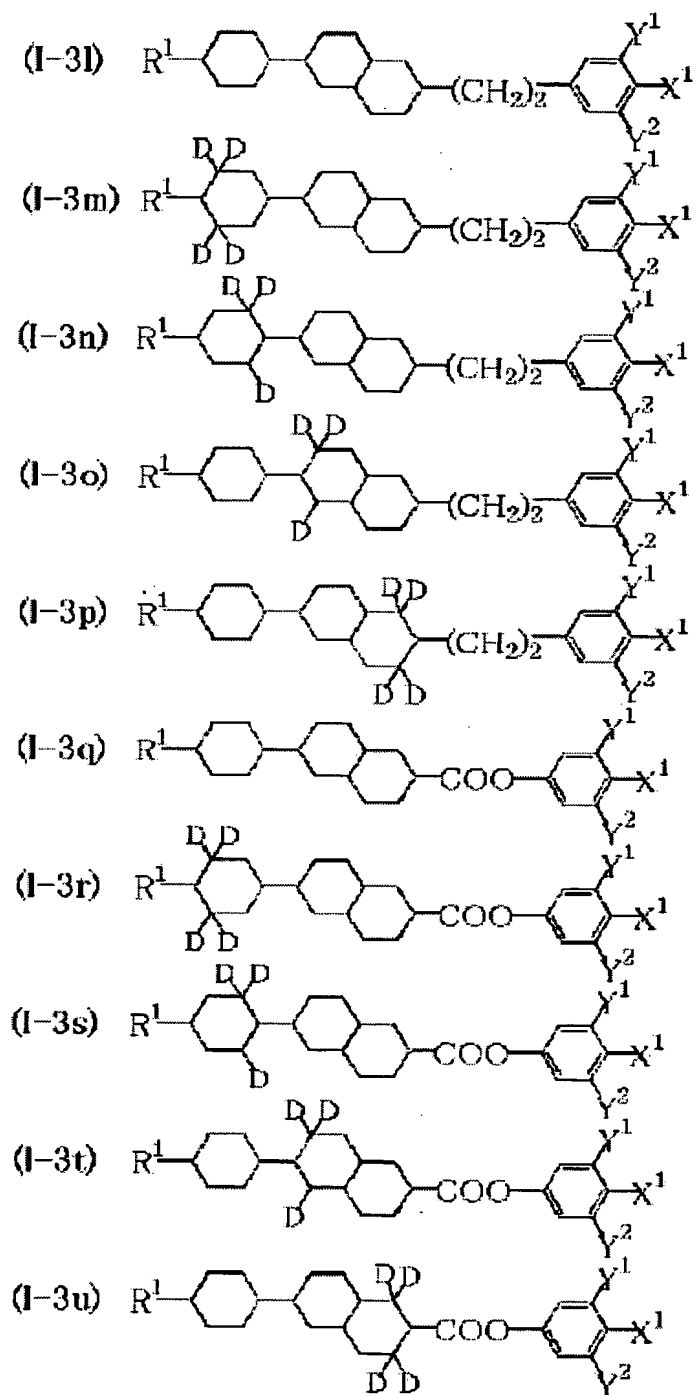
[0071]

[Chemical Formula 25]



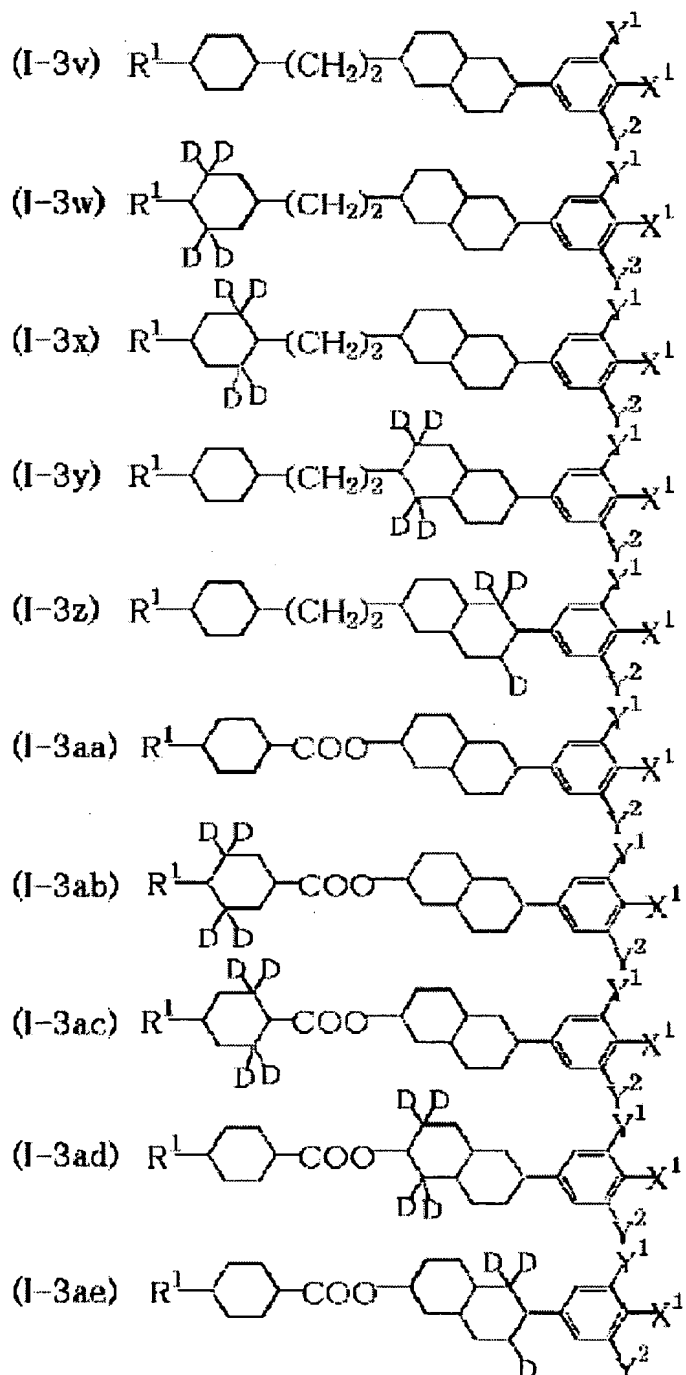
[0072]

[Chemical Formula 26]



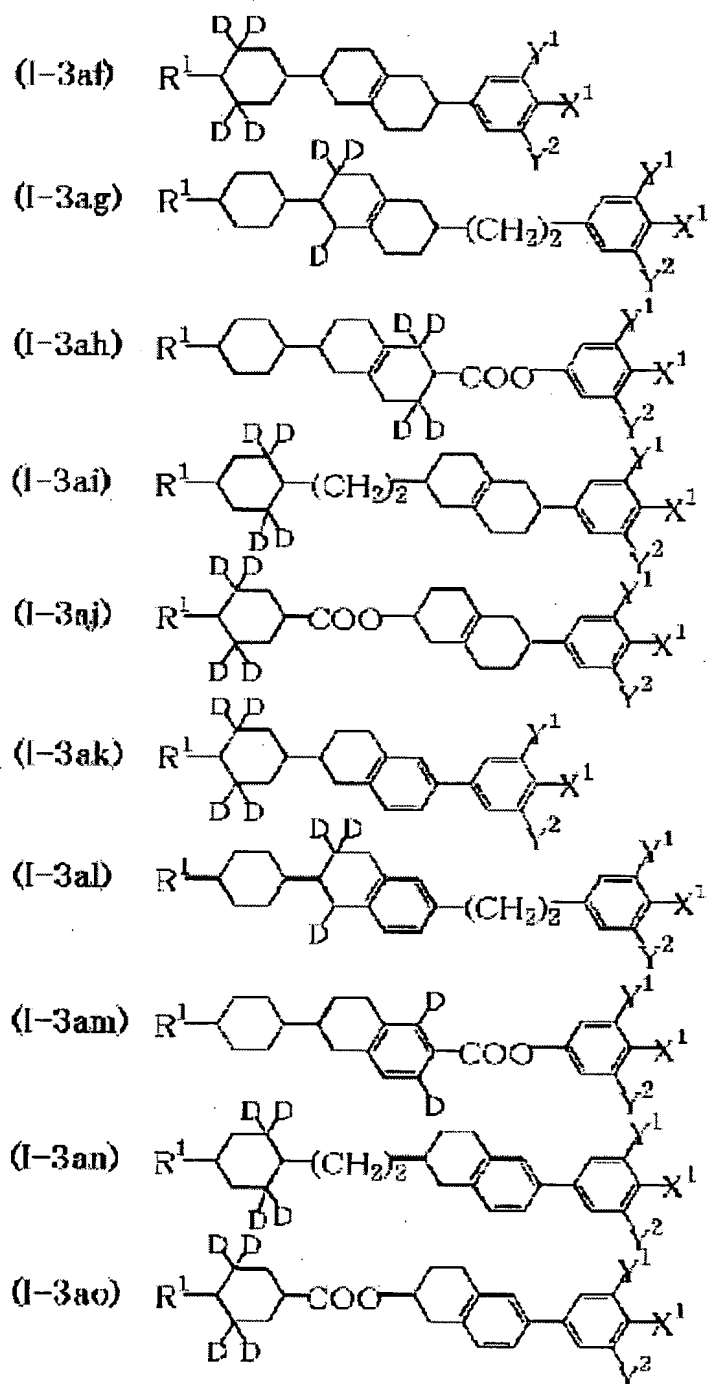
[0073]

[Chemical Formula 27]



[0074]

[Chemical Formula 28]



(I-3ap)

(I-3aq)

(I-3ar)

(I-3as)

(I-3at)

(I-3au)

(I-3av)

(I-3aw)

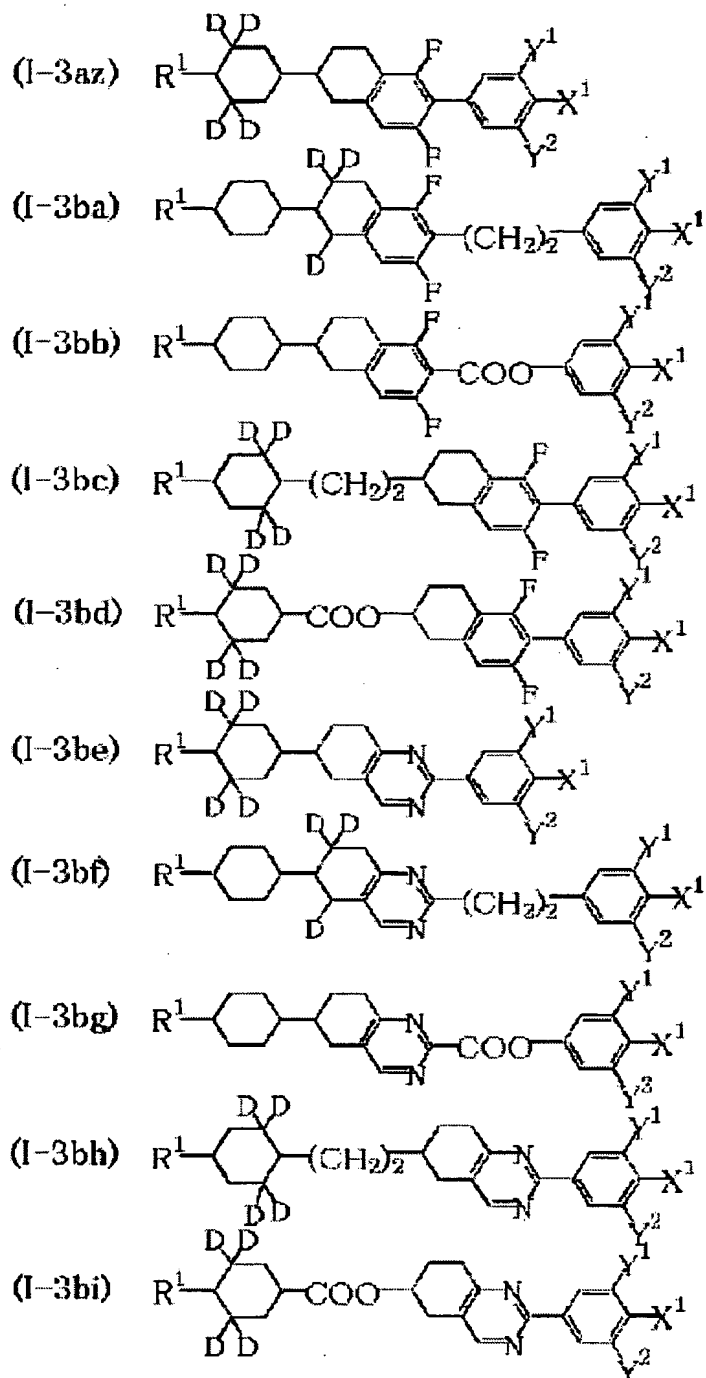
(I-3ax)

(I-3ay)



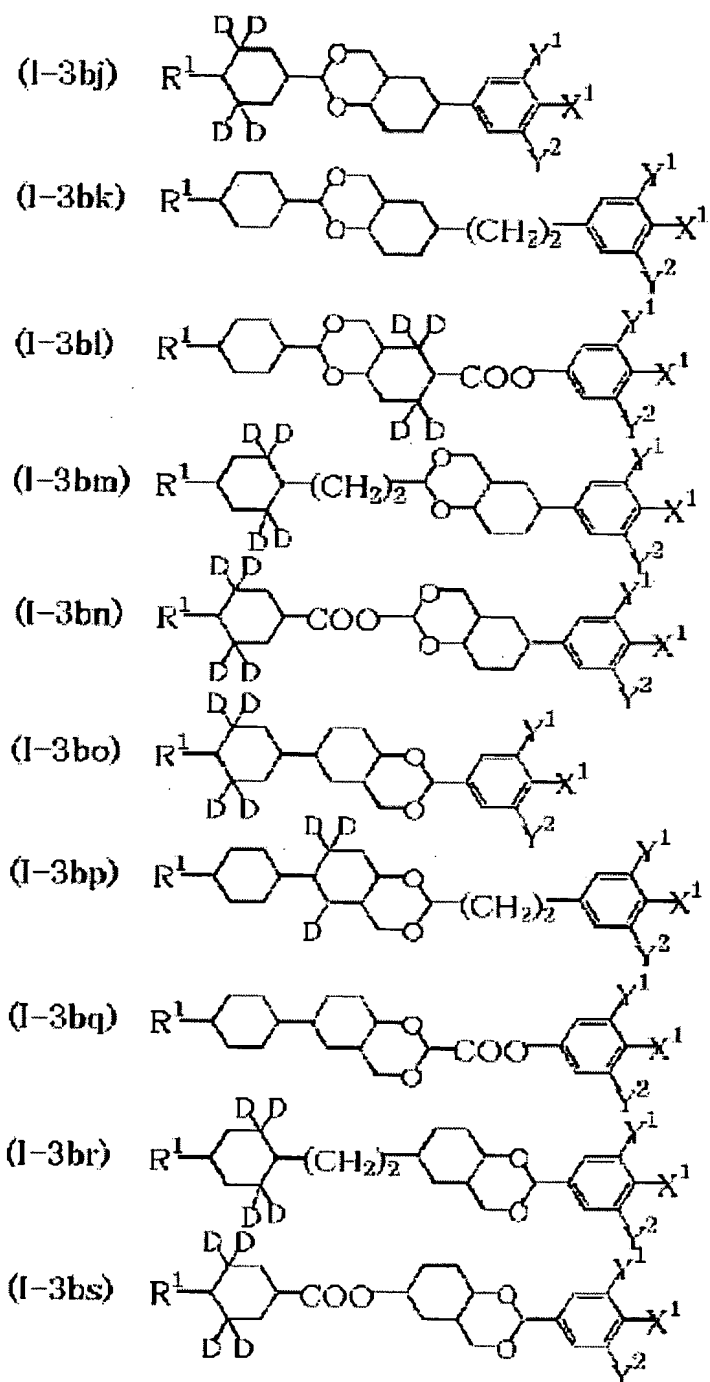
[0076]

[Chemical Formula 30]



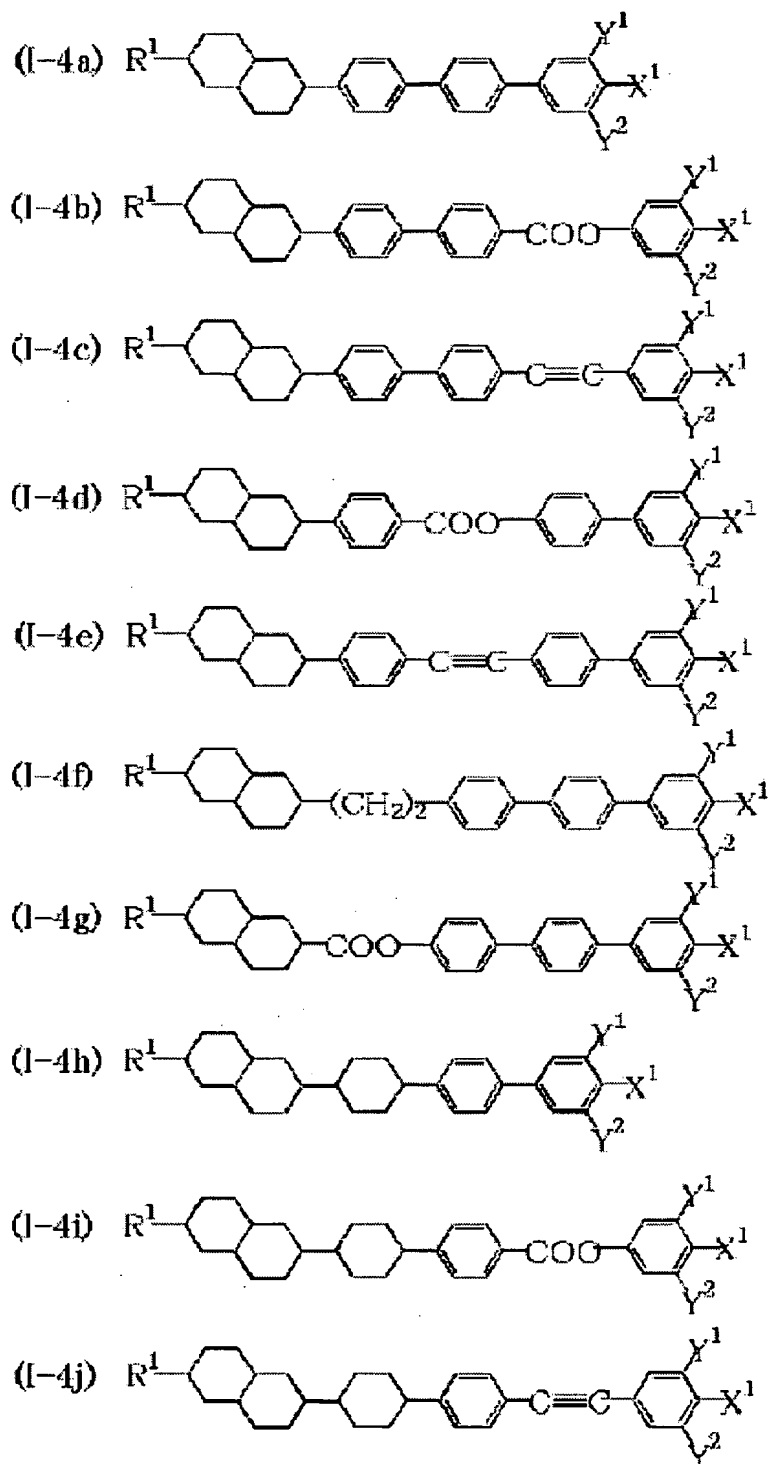
[0077]

[Chemical Formula 31]



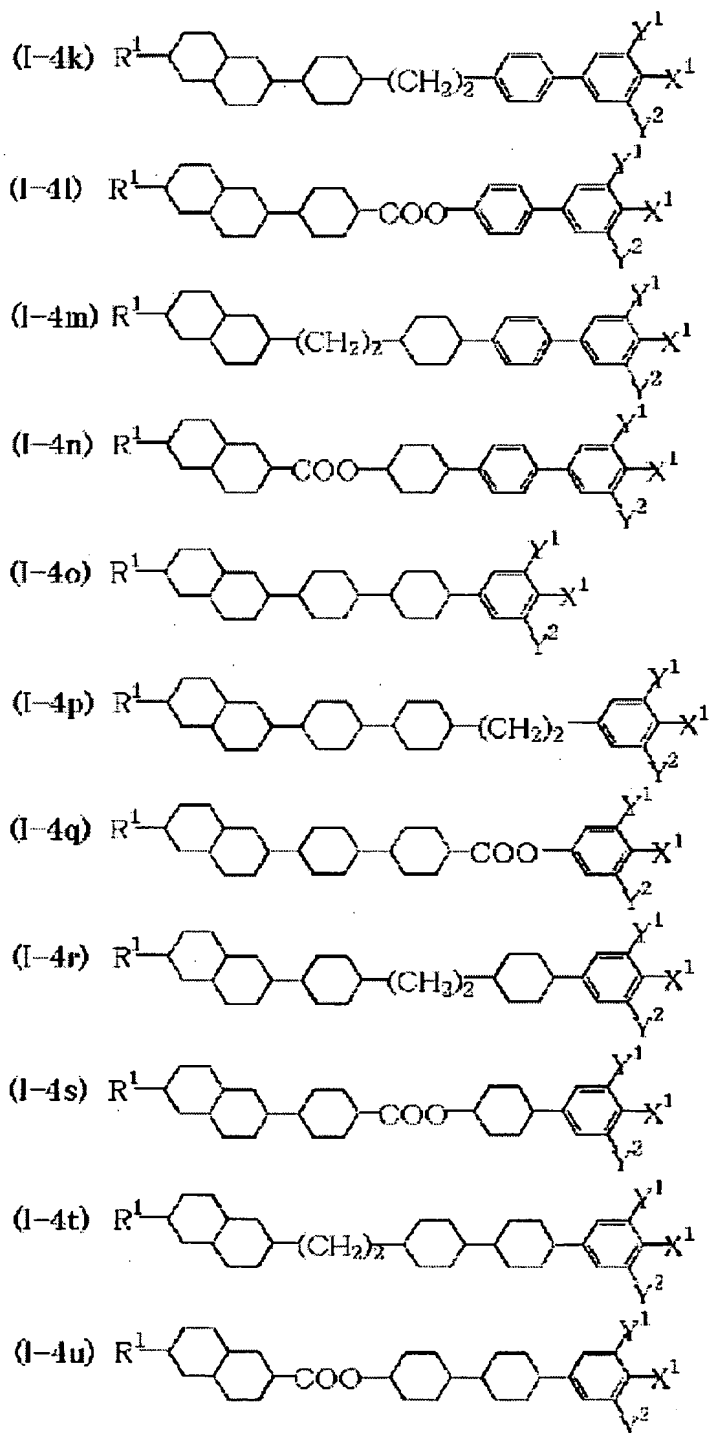
[0078]

[Chemical Formula 32]



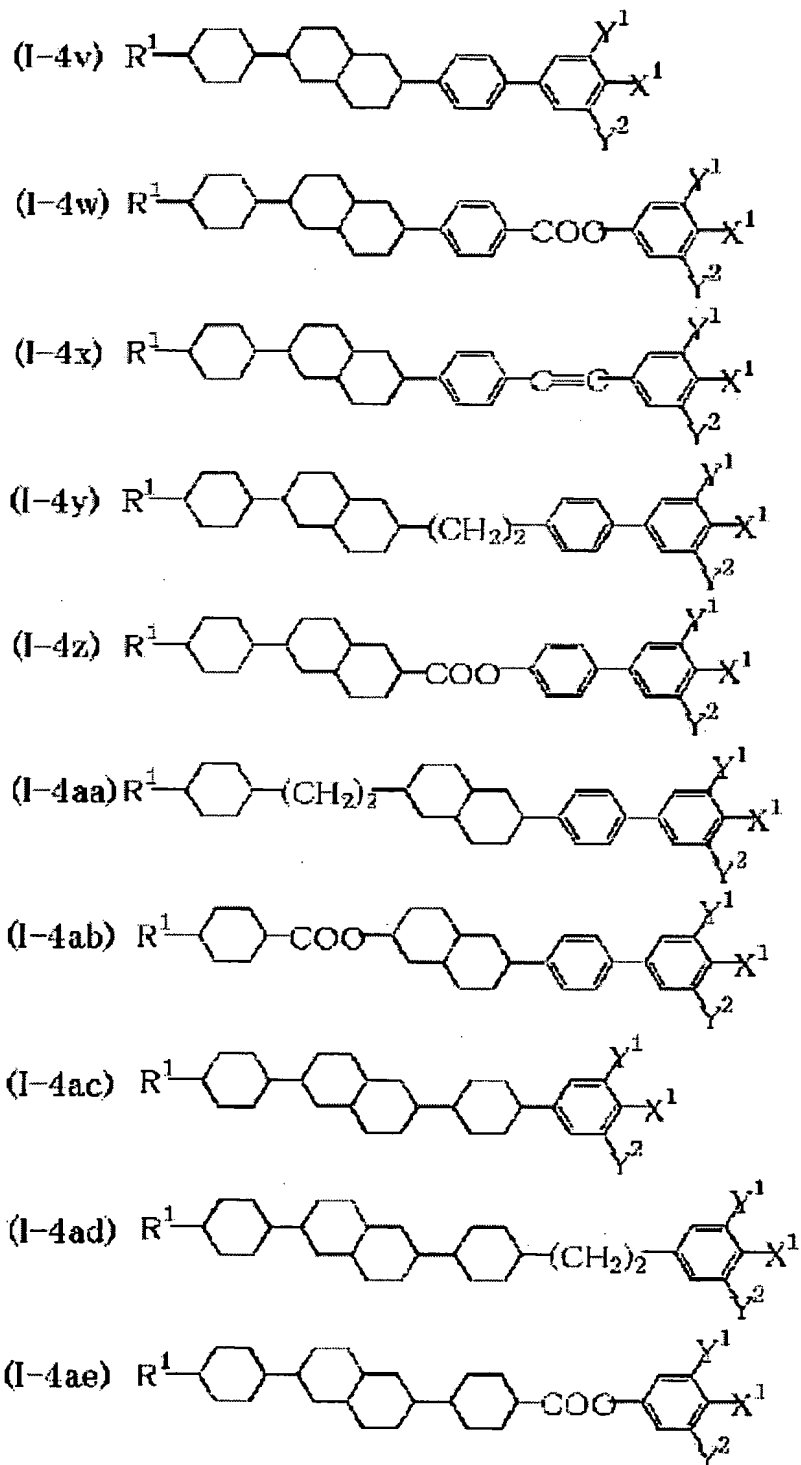
[0079]

[Chemical Formula 33]



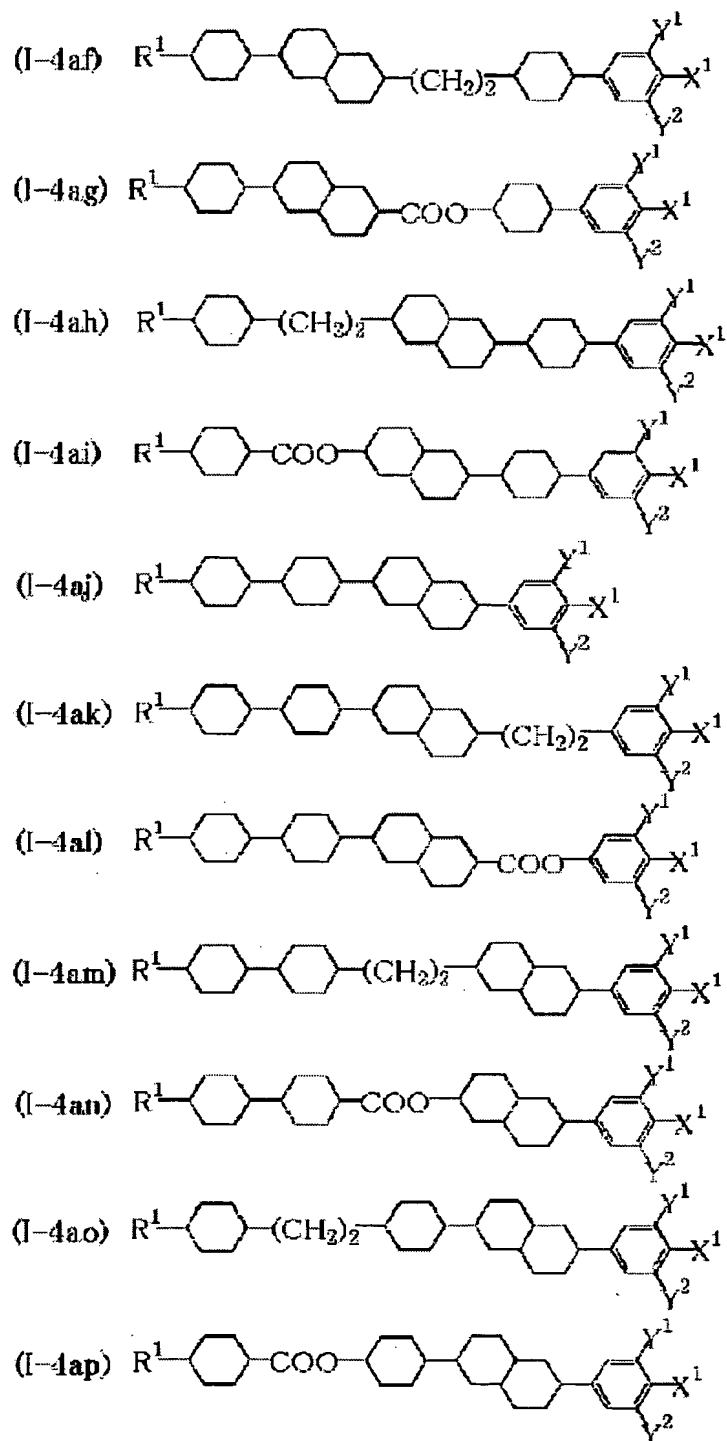
[0080]

[Chemical Formula 34]



[0081]

[Chemical Formula 35]



[0082]

Preferred embodiments of the formula (I-51):

[0083]

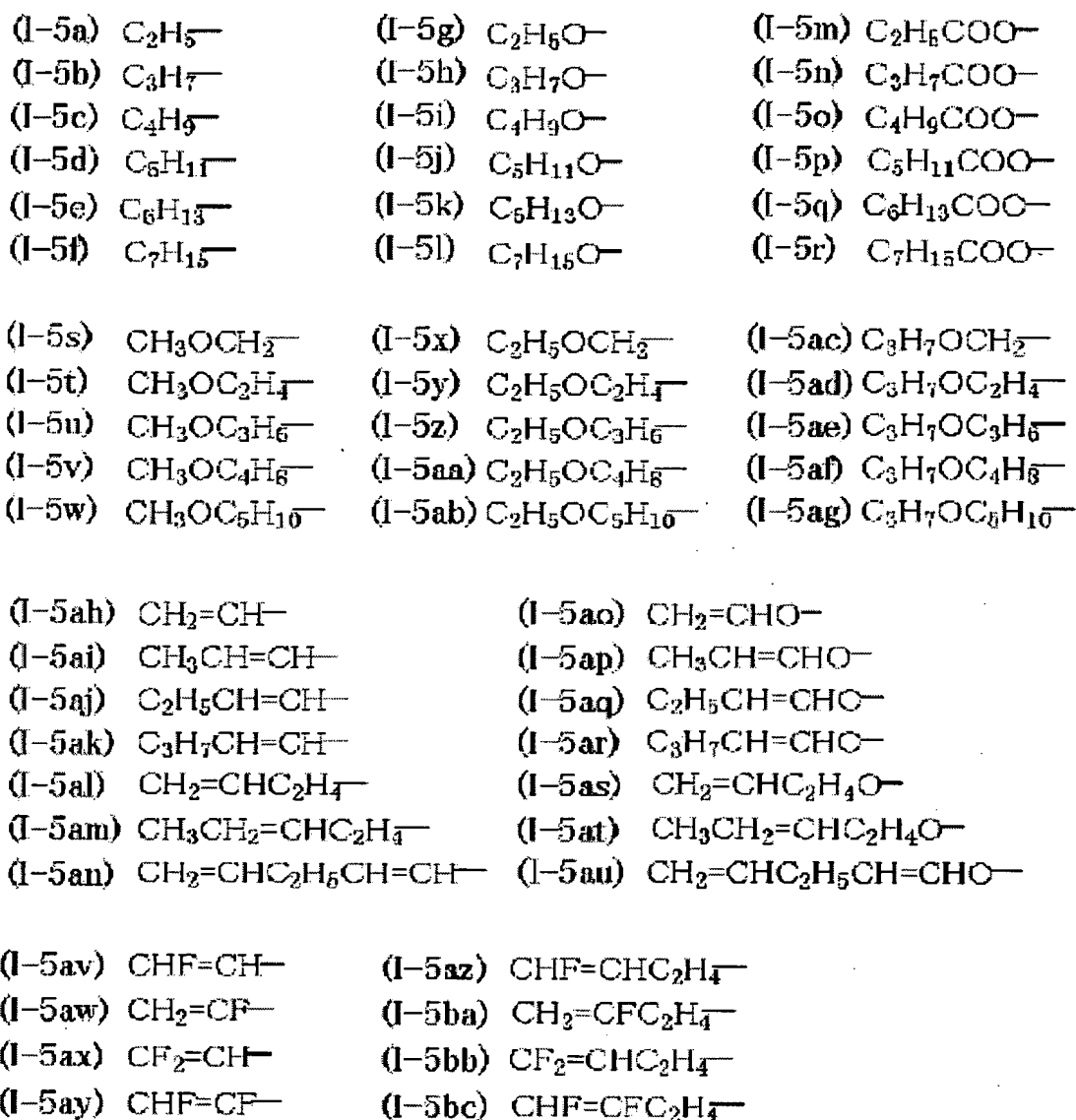
[Chemical Formula 36]

(I-51)  $R^1-$

in a side chain group  $R^1$  include compounds represented by the following general formulas (I-5a) to (I-5bc).

[0084]

[Chemical Formula 37]



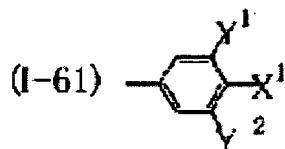


[0085]

More preferred embodiments of the partial structural formula (I-61):

[0086]

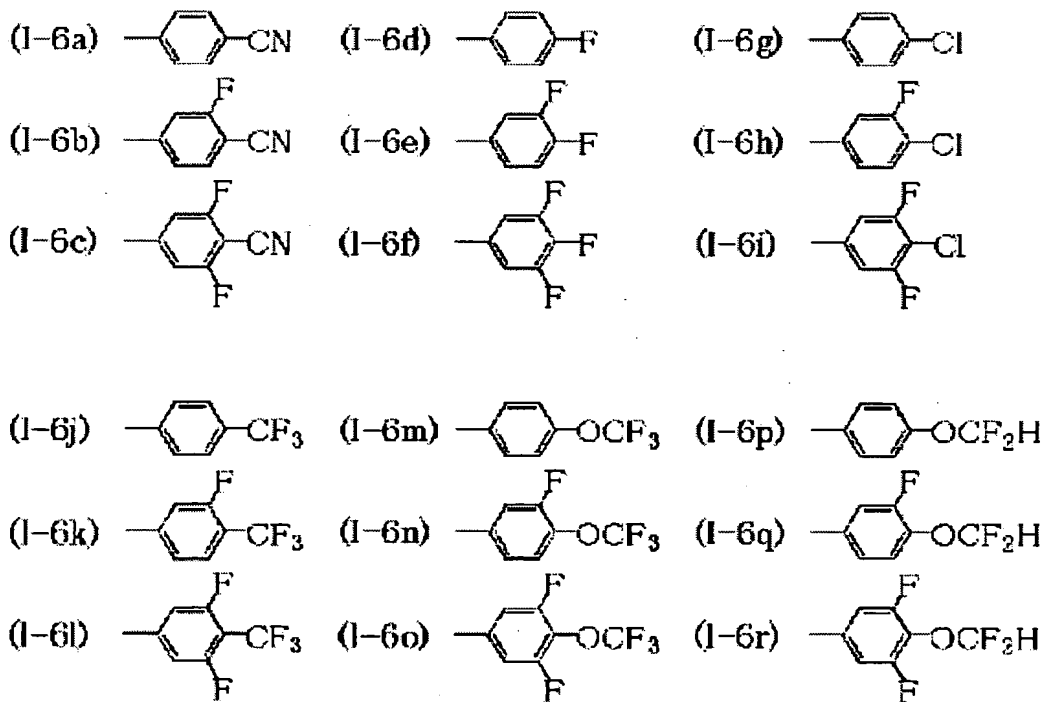
[Chemical Formula 38]



of the 1,4-phenylene polar group having a non-substituted or substituted polar group include compounds represented by the following general formulas (I-6a) to (I-6r).

[0087]

[Chemical Formula 39]

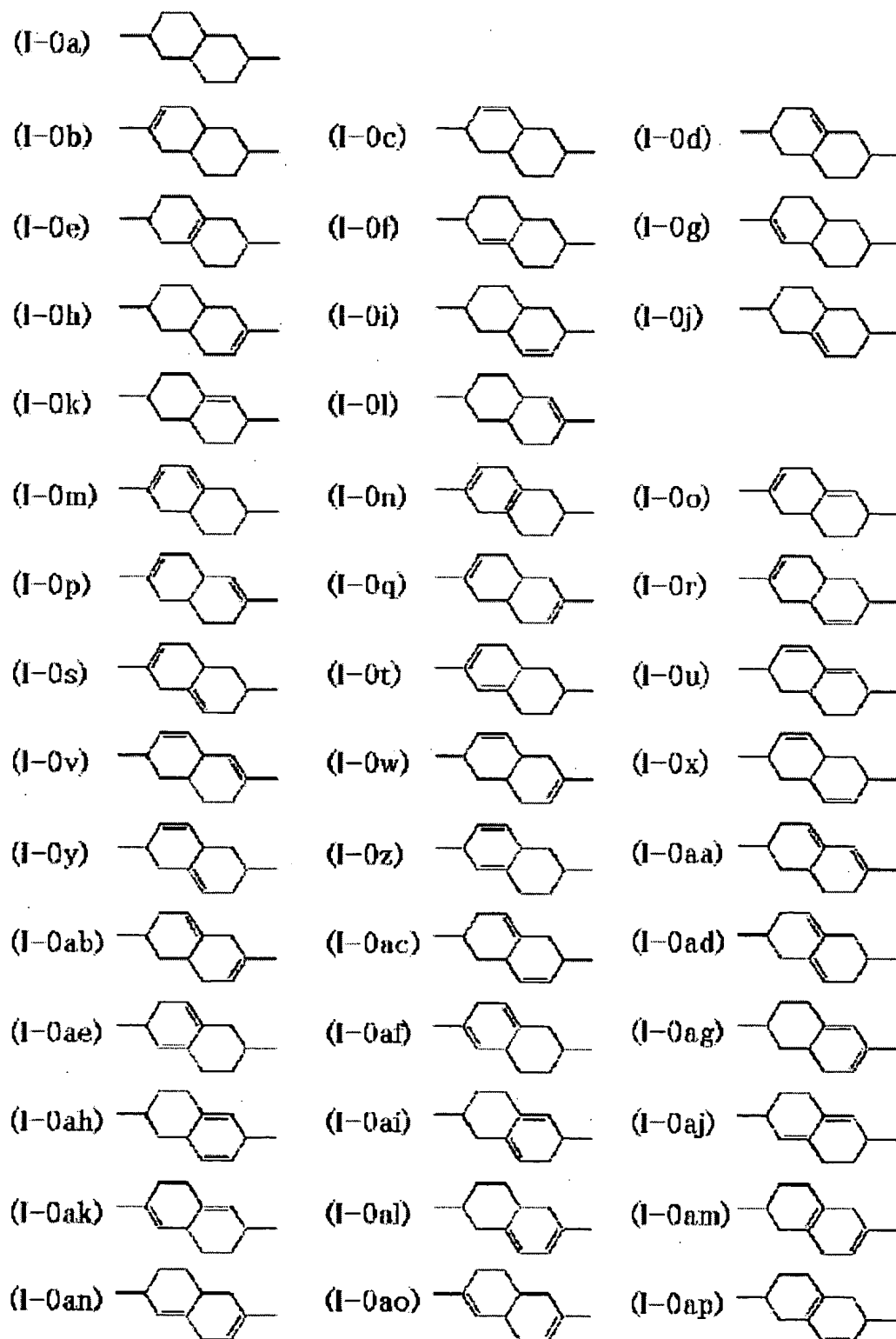


[0088]

According to the present invention, more preferred embodiments of the non-substituted or substituted decahydronaphthalene-2,6-diyl ring are shown in the following general formulas (I-0a) to (I-0dm).

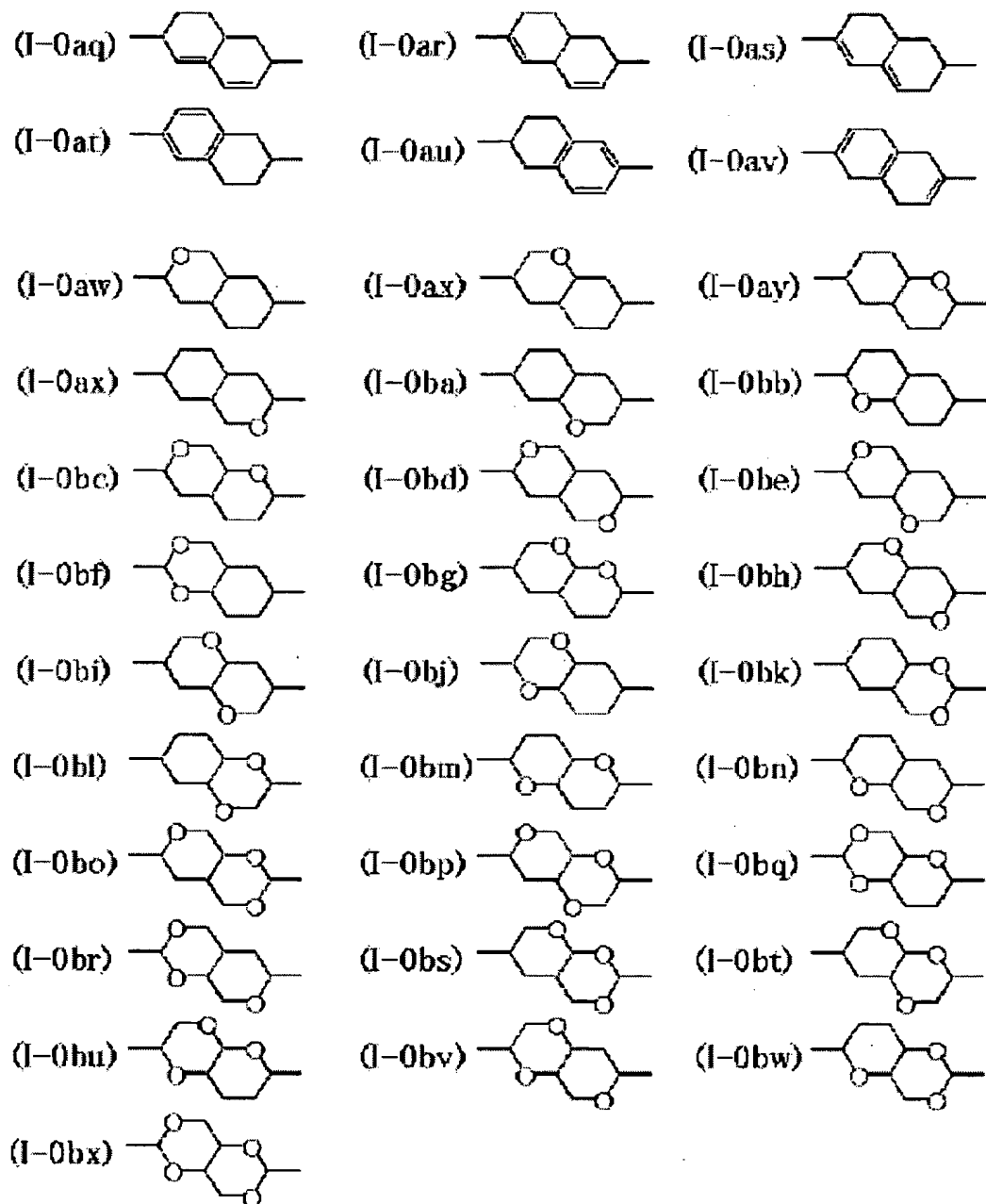
[0089]

[Chemical Formula 40]



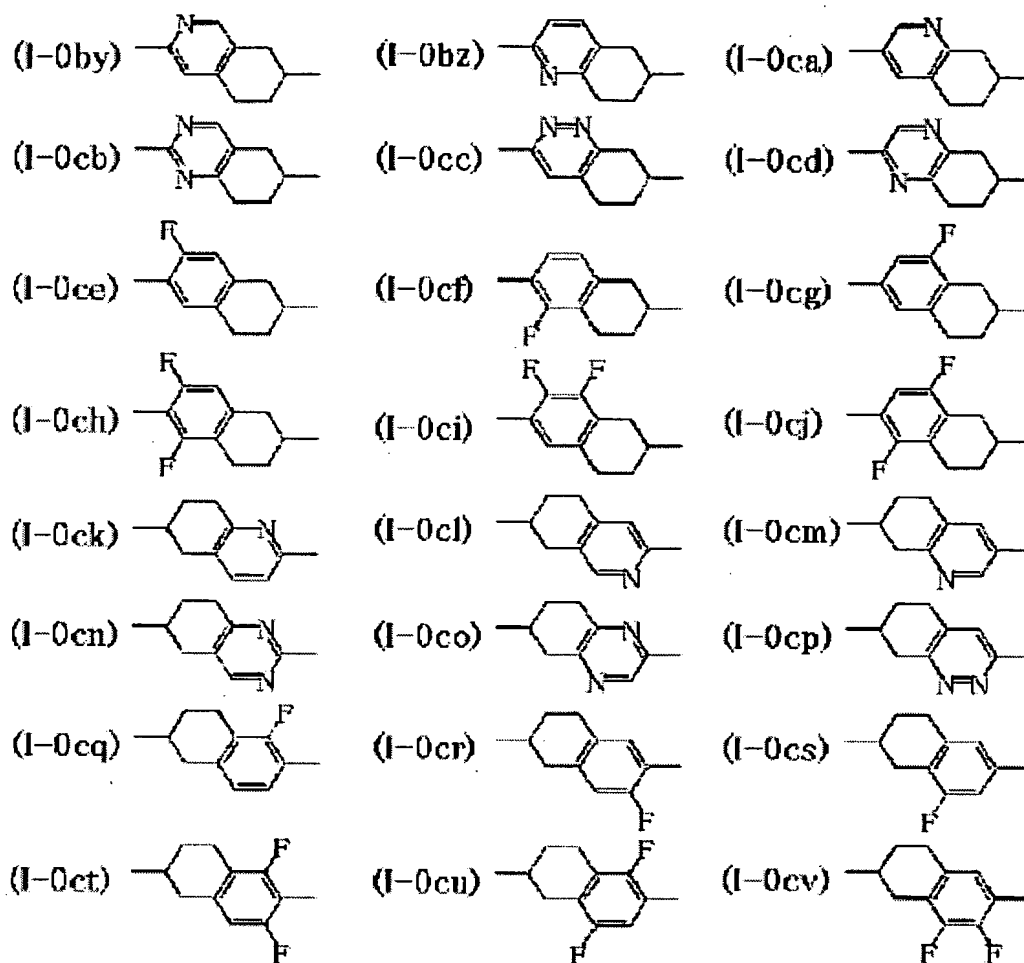
[0090]

[Chemical Formula 41]



[0091]

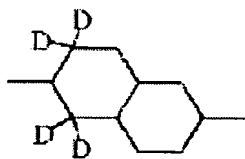
[Chemical Formula 42]



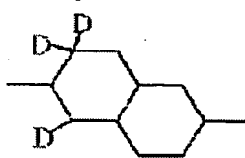
[0092]

[Chemical Formula 43]

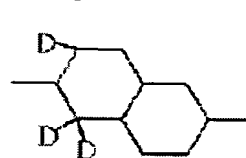
(I-0cw)



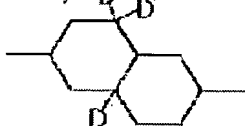
(I-0cx)



(I-0cy)



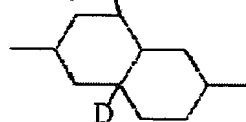
(I-0cz)



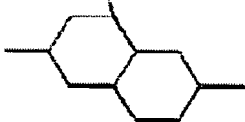
(I-0da)



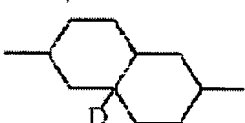
(I-0db)



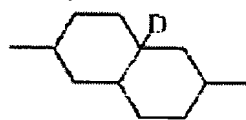
(I-0dc)



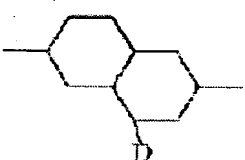
(I-0dd)



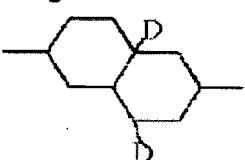
(I-0de)



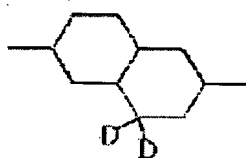
(I-0df)



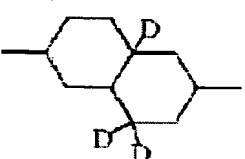
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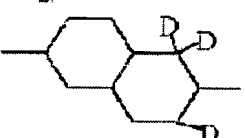
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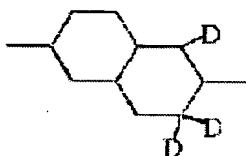
(I-0di)



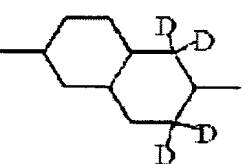
(I-0dj)



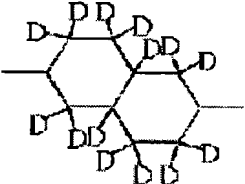
(I-0dk)



(I-0dl)



(I-0dm)



[0093]

The respective compounds are used after sufficient purification by removing impurities using a method such as distillation, column purification, recrystallization or the

like.

[0094]

In more detail, if a general liquid crystal composition is prepared, the following compounds are preferably used as the liquid crystal component A, thereby making it possible to obtain the effects of the present invention.

[0095]

(I-ai): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 7 carbon atoms, in the general formulas (I-1) to (I-4). Specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-4ap) in which the side chain groups are (I-5a) to (I-5f), (I-5ah) to (I-5an) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6r), and preferably compounds having the basic structures of the general formulas (I-1a) to (I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2ad), (I-2ah), (I-2ak) to (I-2bl), (I-2bn) to (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4a) to (I-4ap), and more preferably compounds having the basic structures of the general formulas (I-1a) to (I-1k), (I-1x) to (I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2u), (I-2ah), (I-2ak) to (I-2am), (I-2ao) to (I-2ar), (I-2at), (I-2az), (I-2be) to (I-2bg), (I-2bj) to (I-2bl), (I-2bo), (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3g), (I-3l), (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-

3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4v) to (I-4ap) which broaden the operating temperature range and adjust the elastic constant and its ratio  $K_{33}/K_{11}$  and  $K_{33}/K_{22}$  by an improvement in co-solubility of the liquid crystal composition and an improvement in the holding ratio at low temperatures, thus obtaining more improved electro-optical characteristics of STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like.

[0096]

(I-aii): Compounds in which  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ ,  $OCF_2H$ , or CN, in the general formulas (I-1) to (I-4). Specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-4ap) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6r), and preferably compounds having the basic structures of the general formulas (I-1a) to (I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2ad), (I-2ah), (I-2ak) to (I-2bl), (I-2bn) to (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4a) to (I-4ap), and more preferably compounds having the basic structures of the general formulas (I-1a) to (I-1k), (I-1x) to (I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2u), (I-2ah), (I-2ak) to (I-2am), (I-2ao) to (I-2ar), (I-2at), (I-2az), (I-2be) to (I-2bg), (I-2bj) to (I-2bl), (I-2bo), (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3g), (I-3l), (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-



3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4v) to (I-4ap). If compounds (I-6d) to (I-6r) in which  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$  or  $OCF_2H$  are used practically as a principal component, the resulting liquid crystal is suited for use as a high-reliability STN-LCD as well as an active TFT-LCD, STN-LCD, PDLC and PN-LCD, and is superior in reduction in driving voltage and high voltage holding ratio. When compounds in which  $X^1$  is CN, F or Cl are used practically as a principal component, it becomes possible to obtain excellent electro-optical characteristics such as driving voltage, sharpness, response characteristics and temperature characteristics of TN-LCDs, STN-LCDs, PDLCs, PN-LCDs or the like.

[0097]

(I-aiii): Compounds in which  $Y^1$  and  $Y^2$  represent H, F, Cl,  $CF_3$ , or  $OCF_3$ , in the general formulas (I-1) to (I-4). Specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-4ap) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6r), and preferably compounds having the basic structures of the general formulas (I-1a) to (I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2ad), (I-2ah), (I-2ak) to (I-2bl), (I-2bn) to (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4a) to (I-4ap), and more preferably compounds having the basic structures of the general formulas (I-1a) to (I-1k), (I-1x) to

(I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2u), (I-2ah), (I-2ak) to (I-2am), (I-2ao) to (I-2ar), (I-2at), (I-2az), (I-2be) to (I-2bg), (I-2bj) to (I-2bl), (I-2bo), (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3g), (I-3l), (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4v) to (I-4ap). If compounds (I-6e), (I-6f), (I-6h), (I-6i), (I-6k), (I-6l), (I-6n), (I-6o), (I-6q) and (I-6r) in which at least one or both of  $Y^{11}$  and  $Y^{12}$  represent F or Cl and  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$  are contained practically as a principal component, the resulting liquid crystal is superior in reduction in driving voltage and high voltage holding ratio of active TFT-LCD, STN-LCD, PDLCD and PN-LCD. If compounds (I-6b), (I-6c), (I-6e), (I-6f), (I-6h) and (I-6i) in which  $X^1$  is F, Cl, or CN are used practically as a principal component, it becomes possible to obtain excellent electro-optical characteristics such as driving voltage, sharpness, response characteristics and temperature characteristics of TN-LCDs, STN-LCDs, PDLCDs, PN-LCDs or the like.

[0098]

(I-aiv): Compounds in which  $Z^1$  to  $Z^3$  represent a single bond,  $-(CH_2)_2-$ ,  $-COO-$ , or  $-C\equiv C-$ , in the general formulas (I-1) to (I-4). Specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-4ap) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6r), and preferably compounds having the

basic structures of the general formulas (I-1a) to (I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2ad), (I-2ah), (I-2ak) to (I-2bl), (I-2bn) to (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4a) to (I-4ap), and more preferably compounds having the basic structures of the general formulas (I-1a) to (I-1k), (I-1x) to (I-1aa), (I-1af) to (I-1ai), (I-2a) to (I-2u), (I-2ah), (I-2ak) to (I-2am), (I-2ao) to (I-2ar), (I-2at), (I-2az), (I-2be) to (I-2bg), (I-2bj) to (I-2bl), (I-2bo), (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3g), (I-3l), (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4v) to (I-4ap). Compounds in which  $Z^1$  to  $Z^3$  represent a single bond broaden the operating temperature range by an improvement in co-solubility of the liquid crystal composition and an improvement in storage at low temperature, thereby attaining comparatively fast response characteristics for a predetermined driving voltage. Compounds in which  $Z^1$  to  $Z^3$  represent  $-(CH_2)_2-$  can broaden the operating temperature range by an improvement in co-solubility of the liquid crystal composition and an improvement in storage at low temperature, thereby attaining comparatively fast response characteristics for a predetermined driving voltage. Compounds in which  $Z^1$  to  $Z^3$  represent  $-COO-$  broaden the operating temperature range by an improvement in co-solubility of the liquid crystal composition and an improvement in storage at low temperature,

thereby making it possible to reduce the driving voltage and to improve a change in temperature. Compound in which  $Z^1$  to  $Z^3$  represent  $-C\equiv C-$  adjust the birefringent index within a wide range, thereby making it possible to reduce the driving voltage and to improve a change in temperature. Thus, improved electro-optical characteristics of STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like can be obtained.

[0099]

(I-av): Compounds in which rings  $A^1$  and  $A^2$  represent trans-1,4-cyclohexylene, 1,4-phenylene, 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene, in the general formulas (I-2) to (I-4), and specific compounds are compounds having the basic structures of the general formulas (I-2a) to (I-2ag), (I-2ak) to (I-2an), (I-2ap) to (I-2as), (I-2au) to (I-2ax), (I-2az) to (I-2bc), (I-2be) to (I-2bh), (I-2bj) to (I-2bm) and (I-2bo) to (I-4ap) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6r), and preferably compounds having the basic structures of the general formulas (I-2a) to (I-2ad), (I-2ak) to (I-2an), (I-2ap) to (I-2as), (I-2au) to (I-2ax), (I-2az) to (I-2bc), (I-2be) to (I-2bh), (I-2bj) to (I-2bl), (I-2bo) to (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4a) to (I-4ap), and more preferably compounds having the basic structures of the general formulas (I-2a) to (I-2u), (I-2ak) to (I-2am), (I-2ap) to (I-2ar), (I-

2az), (I-2be) to (I-2bg), (I-2bj) to (I-2bl), (I-2bo), (I-2bt), (I-2ca), (I-2cg), (I-2cl), (I-2cr), (I-3a) to (I-3g), (I-3l), (I-3q), (I-3v), (I-3aa), (I-3af), (I-3ak), (I-3am), (I-3ap), (I-3ar), (I-3au), (I-3aw), (I-3az), (I-3bb), (I-3be) and (I-4v) to (I-4ap), thus obtaining more improved electro-optical characteristics.

Particularly, compounds having both structural features of (I-aiv) and (I-av) exhibit further differentiated characteristics and therefore used in the liquid crystal composition more widely.

(I-av-a): Compounds in which  $Z^1$  to  $Z^3$  represent a single bond and rings  $A^1$  and  $A^2$  represent 1,4-phenylene, 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene have medium or high birefringent index and comparatively large dielectric constant anisotropy, in the general formulas (I-1) to (I-4);

(I-av-b) (I-avii): compounds in which  $Z^1$  to  $Z^3$  represent a single bond and rings  $A^1$  and  $A^2$  represent trans-1,4-cyclohexylene have comparatively fast response characteristics because of broadened nematic phase, in the general formulas (I-1) to (I-4);

(I-av-c) (I-aviii): compounds in which  $Z^1$  to  $Z^3$  represent  $-(CH_2)_2-$  and rings  $A^1$  and  $A^2$  represent trans-1,4-cyclohexylene have good co-solubility, in the general formulas (I-1) to (I-4);

(I-av-d) (I-aix): compounds in which  $Z^1$  to  $Z^3$  represent  $-COO-$  and rings  $A^1$  and  $A^2$  represent 1,4-phenylene, 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene have reduced driving

voltage because of broadened nematic phase, in the general formulas (I-1) to (I-4); and

(I-av-e)(1-ax): compounds in which  $Z^1$  to  $Z^3$  represent  $-C\equiv C-$  and rings  $A^1$  and  $A^2$  represent 1,4-phenylene, 3-fluoro-1,4-phenylene, or 3,5-difluoro-1,4-phenylene have very high or comparatively high birefringent index, in the general formulas (I-1) to (I-4).

(I-avi): Compounds in which at least one hydrogen atom among hydrogen atoms of rings  $A^1$  and  $A^2$  are substituted with a deuterium atom if the rings  $A^1$  and  $A^2$  represent trans-1,4-cyclohexylene, in the general formulas (I-1) to (I-4). These compounds are useful to adjust the elastic constant of the liquid crystal composition and to adjust the pre-tilt angle corresponding to the alignment film and therefore contain preferably at least one compound substituted with a deuterium atom.

[0100]

Although the liquid crystal component A of the present invention can contain one, or two or more kinds of compounds selected from one, two, or three or more compounds among the sub-groups (I-ai) to (I-avi), the effects can be obtained even when composed of only one compound from one sub-group. Compounds having two or more structural features of the compounds shown in the sub-groups (I-ai) to (I-avi) are more preferred. The liquid crystal component A can be composed of the compounds shown in the sub-groups (I-ai) to (I-avi) according to the desired purposes. The liquid crystal

composition containing such a liquid crystal component A of the present invention broadens the operating temperature range of liquid crystal display characteristics due to an improvement in co-solubility and storage at low temperature, thereby making it possible to improve a reduction in driving voltage and a change in temperature and to attain comparatively fast response characteristics for a predetermined driving voltage, thus obtaining more improved electro-optical characteristics of TN-LCDs, STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like using the liquid crystal composition as a constituent material.

[0101]

For the purpose of obtaining a liquid crystal composition suited for use as TN-LCD, STN-LCD, PDLC, PN-LCD or the like, compounds in which  $X^1$  is CN in the general formulas (I-1) to (I-4) are preferably used. In this case, the liquid crystal composition can contain, as the liquid crystal component A, one to twenty kinds of compounds selected from one, two, three or more kinds of the general formulas among the general formulas (I-1) to (I-4). The compounds are more preferably compounds selected from compounds of the general formulas (I-1) to (I-3), still more preferably compounds selected from compounds of the general formulas (I-1) and (I-2) or the general formulas (I-1) and (I-3), and particularly preferably compounds selected from compounds of the general formula (1-1). In case of containing the compound of the general formula (I-1), preferred is a liquid crystal component A containing

one to twenty kinds of one, two, or three or more compounds among the sub-groups (I-bi) to (I-biv), the content of the compounds being within a range from 5 to 100% by weight.

[0102]

(I-bi) Compounds in which  $R^1$  is an alkenyl group having 2 to 7 carbon atoms, and specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-1ai) in which the side chain groups are (I-5ah) to (I-5an) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6c).

(I-bii) Compounds in which one of  $Y^1$  and  $Y^2$  is F, Cl, or  $OCF_3$ , and specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-1ai) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6b) and (I-6c).

(I-biii) Compounds in which  $Z^1$  represent  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ , or  $-C\equiv C-$ , and specific compounds are compounds having the basic structures of the general formulas (I-1o) to (I-1aa), (I-1ac), (I-1ad) and (I-1af) to (I-1ai) in which the side chain groups are (I-6a) to (I-6c) and the partial structures of the polar group are represented by the general formulas (I-6a) and (I-6c).

(I-biv): Compounds in which the decahydronaphthalene-2,6-diyl group has at least substituent among substituents of  $-CH_2-$ ,  $O-$ ,  $-CH=CH-$ ,  $-CH=CF-$ ,  $-CF=CF-$ ,  $-CH=N-$ ,  $-CF=N-$ ,  $>CH-O-$ ,  $>C=CH-$ ,  $>C=CF-$ ,  $>C=N-$ ,  $>N-CH_2-$ ,  $>CH-CF<$ ,  $>CF-CF<$  and  $>C=C<$ , and



specific compounds are compounds having the basic structures of the general formulas (I-1a), (I-1o), (I-1s), (I-1t) and (I-1ab) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6c) in which the decahydronaphthalene-2,6-diyl group represent compounds (I-0b) to (I-0cv), and more preferably compounds having the basic structures of the general formulas (I-1f) to (I-1n), (I-1p), (I-1w) to (I-1aa) and (I-1ac) to (I-1ai) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6c), and particularly preferably compounds having the basic structures of the general formulas (I-1h) to (I-1k), (I-1x) to (I-1aa) and (I-1af) to (I-1ai). As a matter of course, compounds in which at least one of hydrogen atom, which are present in these rings, is substituted with a deuterium atom are also included.

[0103]

For the purpose of obtaining a liquid crystal composition suited for use as STN-LCD to which high reliability is required, or active STN-LCD, TFT-LCD, PDLC, PN-LCD or the like, compounds in which  $X^1$  is F, Cl,  $CF_3$ , or  $OCF_3$  in the general formulas (I-1) to (I-4) are preferably used. In this case, the liquid crystal composition can contain, as the liquid crystal component A, one to twenty kinds of compounds selected from one, two, three or more kinds of the general formulas among the general formulas (I-1) to (I-4). The

compounds are more preferably compounds selected from compounds of the general formulas (I-1) to (I-3), still more preferably compounds selected from compounds of the general formulas (I-1) and (I-2) or the general formulas (I-1) and (I-3), and particularly preferably compounds selected from compounds of the general formula (I-1). In case of containing the compound of the general formula (I-1), preferred is a liquid crystal component A containing one to twenty kinds of one, two, or three or more compounds among the sub-groups (I-bi) to (I-bviii), the content of the compounds being within a range from 5 to 100% by weight.

[0104]

(I-bv) Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, and specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-1ai) in which the side chain groups are (I-5a) to (I-5ad), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6d) to (I-6r).

(I-bvi) Compounds in which one of  $Y^1$  and  $Y^2$  is F, Cl, or  $OCF_3$ , and specific compounds are compounds having the basic structures of the general formulas (I-1a) to (I-1ai) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6d) to (I-6r).

(I-bvii) Compounds in which  $Z^1$  represent a single bond,  $-(CH_2)_2-$ , or  $-C\equiv C-$ , and specific compounds are compounds

having the basic structures of the general formulas (I-1a) to (I-1r), (I-1ac) and (I-1af) to (I-1ai) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6d) to (I-6r).

(I-bviii): Compounds in which the decahydronaphthalene-2,6-diyl group has at least substituent among substituents of  $-\text{CH}_2-\text{O}-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{CF}-$ ,  $-\text{CF}=\text{CF}-$ ,  $-\text{CH}=\text{N}-$ ,  $-\text{CF}=\text{N}-$ ,  $>\text{CH}-\text{O}-$ ,  $>\text{C}=\text{CH}-$ ,  $>\text{C}=\text{CF}-$ ,  $>\text{C}=\text{N}-$ ,  $>\text{N}-\text{CH}_2-$ ,  $>\text{CH}-\text{CF}<$ ,  $>\text{CF}-\text{CF}<$  and  $>\text{C}=\text{C}<$ , and specific compounds are compounds having the basic structures of the general formulas (I-1a), (I-1o), (I-1s), (I-1t) and (I-1ab) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6d) to (I-6r) in which the decahydronaphthalene-2,6-diyl group represent compounds (I-0b) to (I-0cv), and more preferably compounds having the basic structures of the general formulas (I-1f) to (I-1n), (I-1p), (I-1w) to (I-1aa) and (I-1ac) to (I-1ai) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6c), and particularly preferably compounds having the basic structures of the general formulas (I-1h) to (I-1k), (I-1x) to (I-1aa) and (I-1af) to (I-1ai). As a matter of course, compounds in which at least one of hydrogen atom, which are present in these rings, is substituted with a deuterium atom are also included.

[0105]

(I-bix): Specifically, the non-substituted or substituted decahydronaphthalene-2,6-diyl group of compounds of the general formulas (I-1) to (I-4) related to the present invention is preferably (I-0a) to (I-0dm). More preferred are (I-0a) to (I-0l), (I-0at), (I-0au), (I-0bk) and (I-0by) to (I-0dm), and particularly preferred are (I-0a), (I-0e), (I-0au), (I-0bk), (I-0ck), (I-0cl), (I-0cn), (I-0cq), (I-0cr), (I-0ct) and (I-0cw) to (I-0dm). Particularly, compounds having (I-0cq) had excellent response characteristics and high nematic phase-isotropic liquid phase transition temperature compared to compounds having (I-0au), and also had noticeable properties which are not recognized in the prior art. As a matter of course, compounds in which at least one of hydrogen atom, which are present in the rings of (I-0a) to (I-0cv), is substituted with a deuterium atom are also included.

[0106]

Although the liquid crystal component A of the present invention can contain one, or two or more kinds of compounds selected from one, two, or three or more compounds among the sub-groups (I-bi) to (I-bix), the effects can be obtained even when composed of only one compound from one sub-group. Compounds having two or more structural features of the compounds shown in the sub-groups (I-bi) to (I-bix) are more preferred. The liquid crystal component A can be composed of the compounds shown in the sub-groups (I-bi) to (I-bix) according to the desired purposes.

[0107]

The liquid crystal component A composed of compounds of the general formulas (I-1) to (I-4) related to the liquid crystal composition of the present invention, or the liquid crystal component A containing compounds of the above-described sub-groups (I-ai) to (I-bix), or the liquid crystal component A containing compounds capable of having two or more structural features of the sub-groups (I-ai) to (I-bix) is characterized by a molecular structure having, as a partial structure, a non-substituted or substituted decahydronaphthalene-2,6-diyl group. This feature has a plate-like structure compared to conventional compounds. Therefore, the resulting liquid crystal composition has excellent co-solubility, comparatively high phase transition temperature in spite of its molecular length, comparatively small birefringent index in spite of high phase transition temperature, and lower driving voltage in spite of large dielectric constant anisotropy, thereby exerting the effect of inhibiting the dependence of the frequency on the driving voltage at high frequency range and to reduce the dependence of the temperature on the driving voltage, and is also superior in adjustment of the size of  $K_{22}$ . From such a point of view, the liquid crystal composition is also useful to improve the response characteristics, particularly response characteristics of IPS mode.

[0108]

Although the liquid crystal composition of the present invention can contain one or more kinds of compounds

represented by the general formulas (I-1) to (I-4) as the liquid crystal component A, the effects can be obtained even when composed of only one compound. Liquid crystal component A containing at least one compound represented by the general formula (I-1) or at least one compound represented by the general formula (I-2) and/or at least one compound represented by the general formula (I-3) is more preferred. The liquid crystal composition containing such a liquid crystal component of the present invention broadens the operating temperature range of liquid crystal display characteristics due to an improvement in co-solubility and storage at low temperature, thereby making it possible to improve a reduction in driving voltage and a change in temperature and to attain comparatively fast response characteristics for a predetermined driving voltage, thus obtaining more improved electro-optical characteristics of TN-LCDs, STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like using the liquid crystal composition as a constituent material.

[0109]

The liquid crystal composition of the present invention contains a liquid crystal component B, which contains one, or two or more kinds of compounds having a dielectric constant anisotropy of +2 or more, in addition to the liquid crystal component A. The liquid crystal compound having a dielectric constant anisotropy of +2 or more in the present invention is used in the following meaning. The liquid crystal compound is a compound which has a bar-like chemical structure, the center

portion having a core structure with one to four six-membered rings, the six-membered ring positioned at both terminals in the major axis direction of the center portion having a terminal group substituted at the position corresponding to the direction of the major axis of the liquid crystal, at least one of terminal groups, which are present at both terminals, being a polar group, for example, -F, -Cl, -NO<sub>2</sub>, -CF<sub>3</sub>, -OCF<sub>3</sub>, -OCHF<sub>2</sub>, -CN, -OCN, -NCS or the like. Consequently, it becomes possible to adjust the optical anisotropy of the liquid crystal layer to a predetermined value, thereby making it possible to electrically drive and widen the operating temperature range.

[0110]

As the liquid crystal component B, one, or two or more kinds, preferably three to forty kinds, and more preferably three to fifteen kinds of compound having a dielectric constant anisotropy of +2 or more can be used. The liquid crystal composition preferably contains the compound after appropriately selecting from compound having a dielectric constant anisotropy within a range from +2 to +8, compound having a dielectric constant anisotropy within a range from +8 to +13, compound having a dielectric constant anisotropy within a range from +14 to +18 and compound having a dielectric constant anisotropy of +18 or more. In this case, thirty kinds or less, preferably fifteen kinds or less of compounds having a dielectric constant anisotropy within a range from +2 to +13 are mixed, twenty kinds or less,

preferably eight kinds or less of compounds having a dielectric constant anisotropy within a range from +14 to +18 are mixed, and fifteen kinds or less, preferably ten kinds or less of compounds having a dielectric constant anisotropy of +18 or more are mixed. Use of the liquid crystal component in the above manner exerts more preferred effects due to temperature characteristics of display characteristics. More specifically, it improves the dependence of the temperature on the driving voltage, contrast related to sharpness, response characteristics or the like.

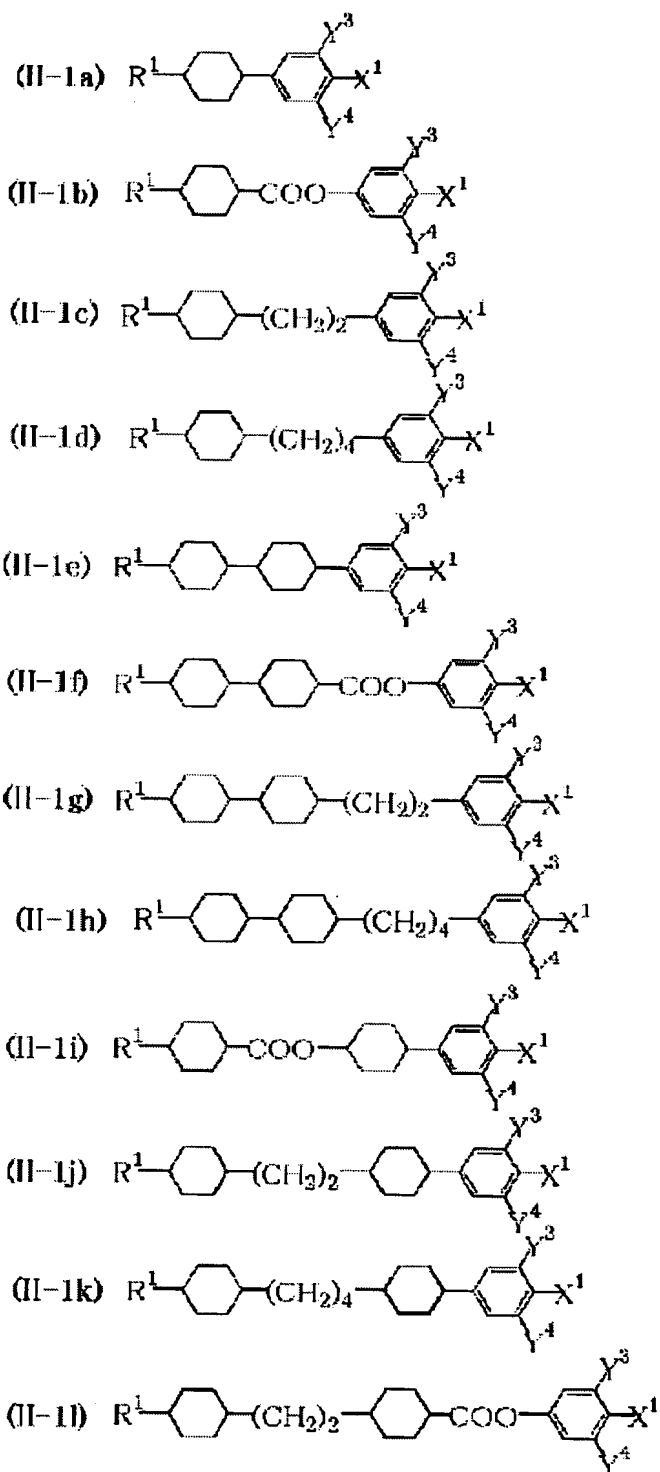
[0111]

From such a point of view, more preferred mode of a basic structure in compounds represented by the general formulas (II-1) to (II-4) includes compounds represented by the general formulas (II-1a) to (II-4g).



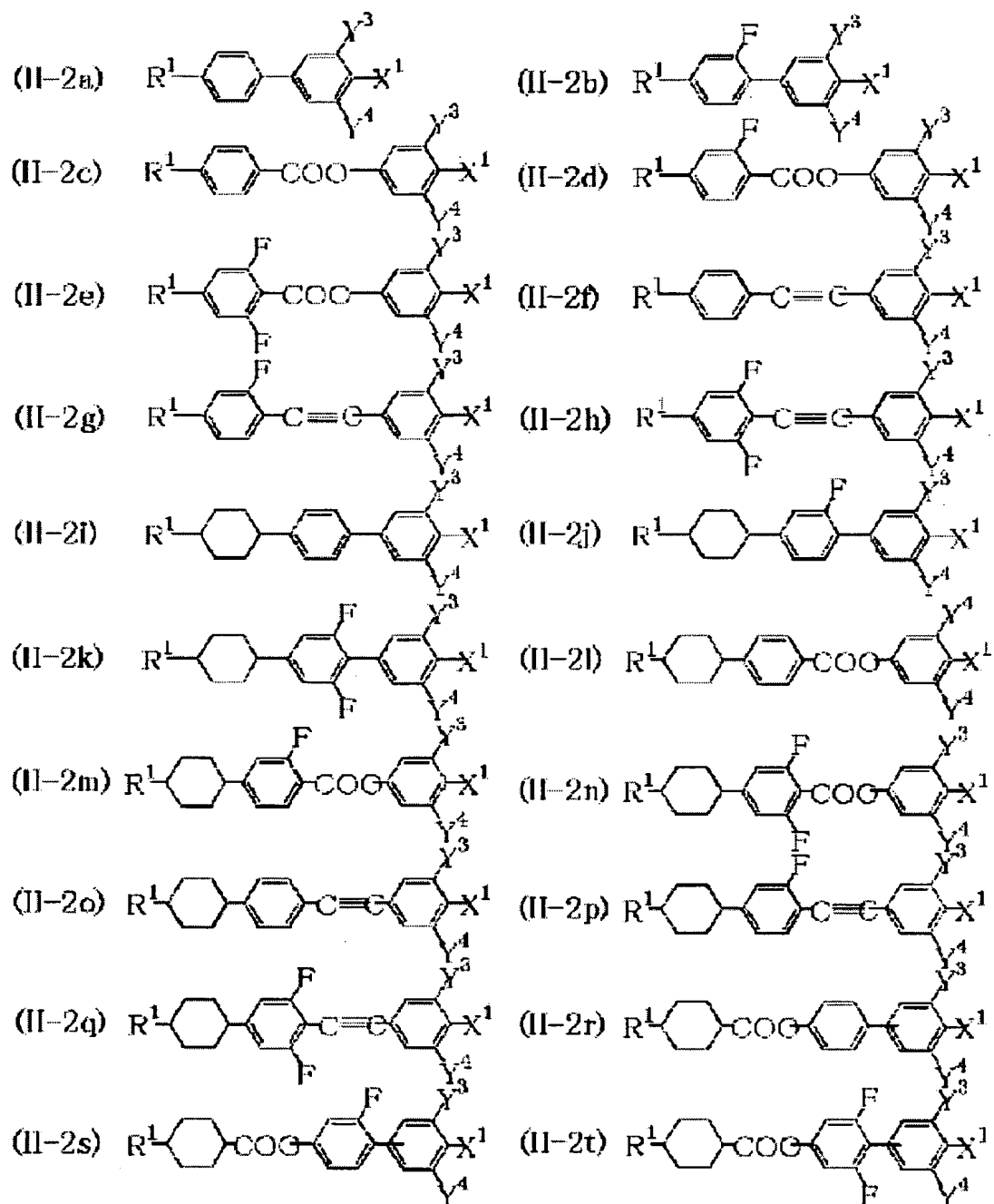
[0112]

[Chemical Formula 44]



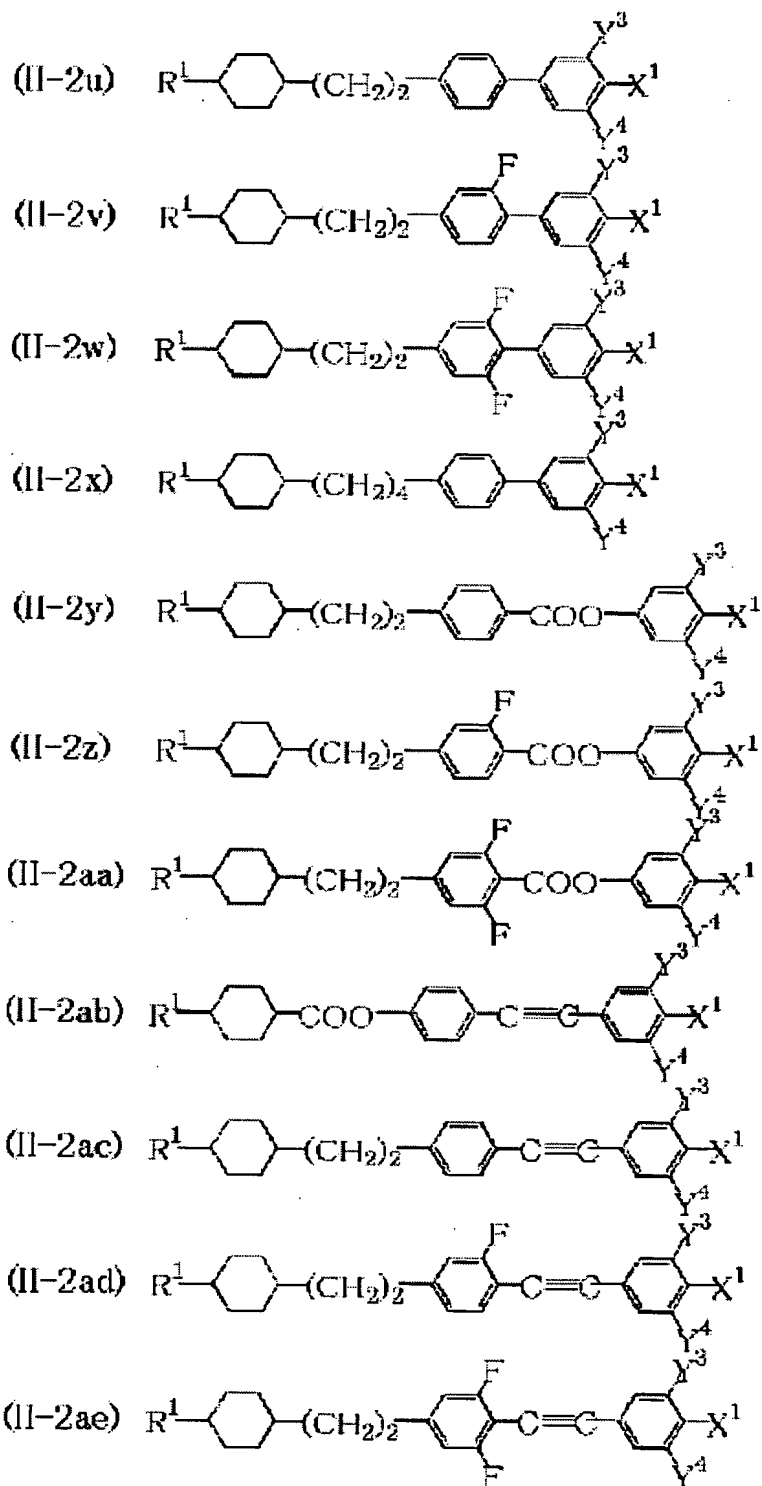
[0113]

[Chemical Formula 45]



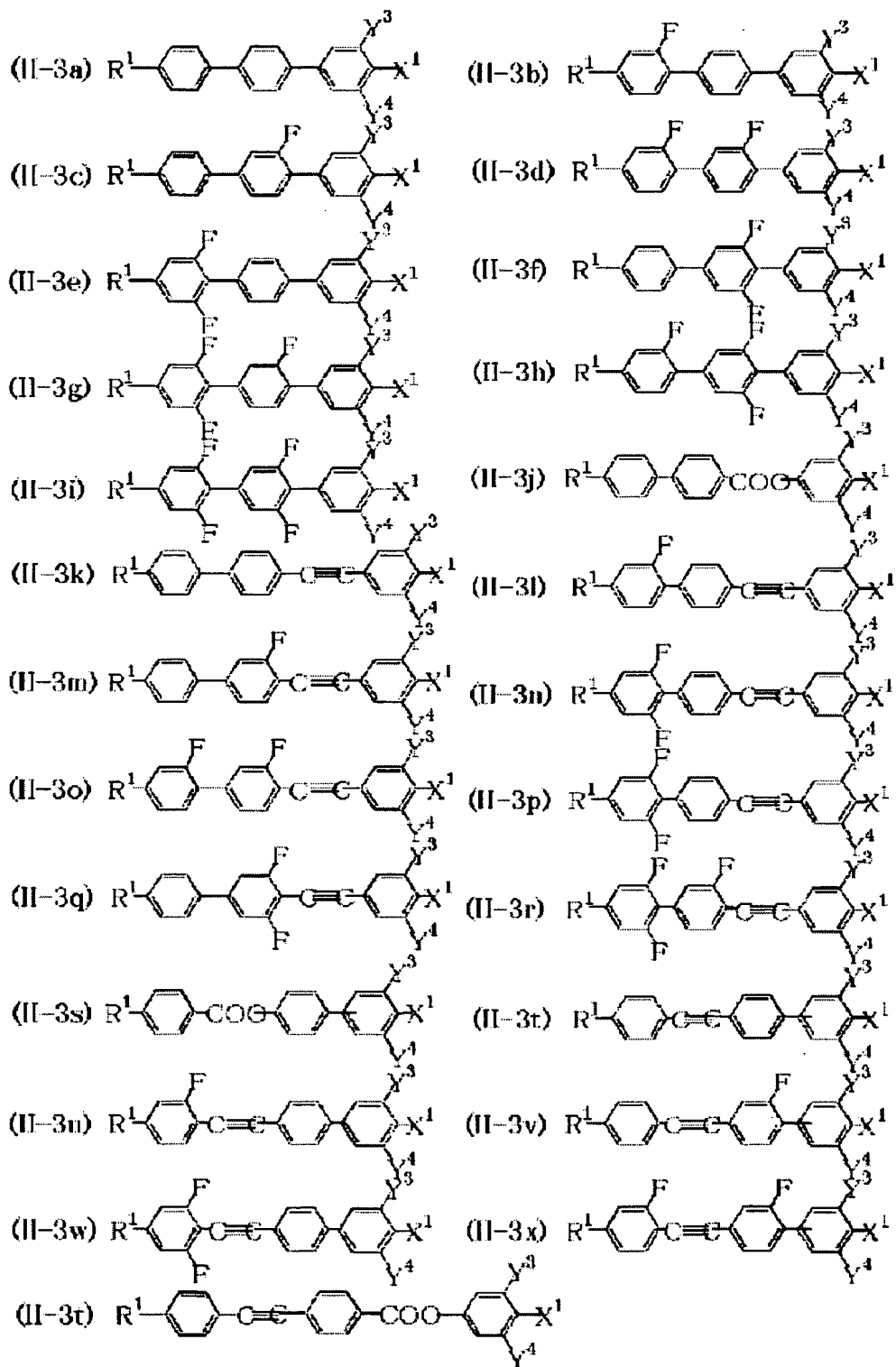
[0114]

[Chemical Formula 46]



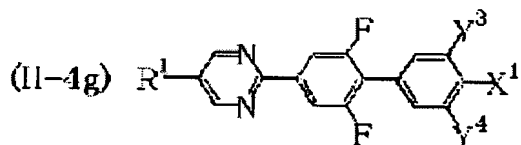
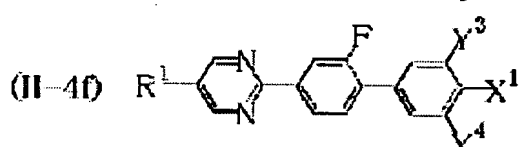
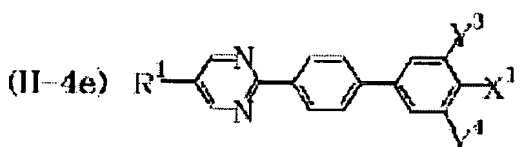
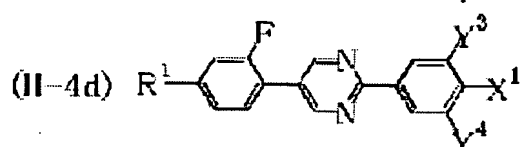
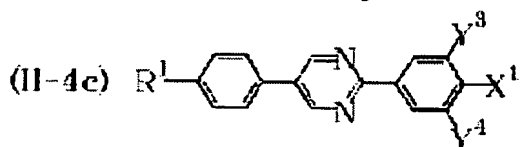
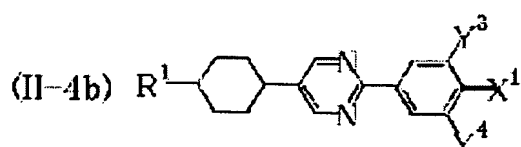
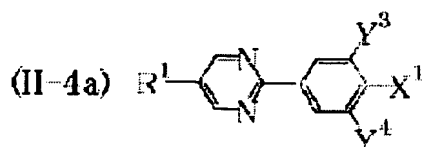
[0115]

[Chemical Formula 47]



[0116]

[Chemical Formula 48]



[0117]

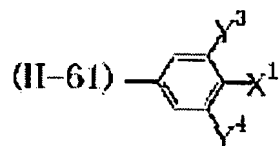
More preferred mode of the side chain group R¹ in the general formulas (II-1) to (II-4) includes compounds of the above-described general formulas (I-5a) to (I-5bc).

[0118]

More preferred mode of the partial structural formula (II-61):

[0119]

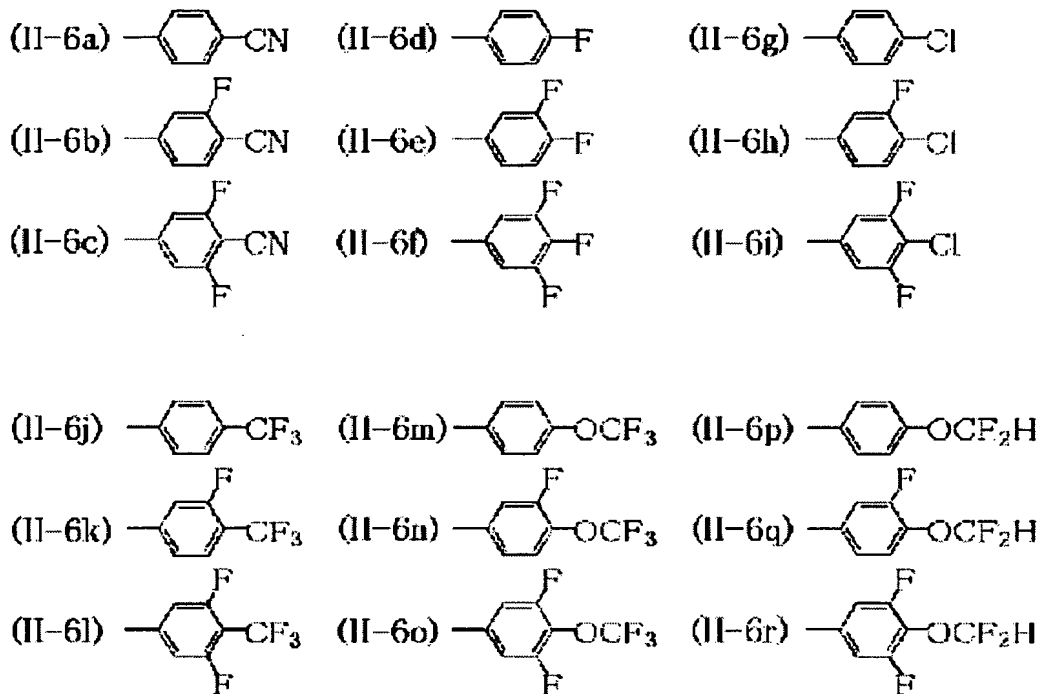
[Chemical Formula 49]



of 1,4-phenylene having a polar group includes compounds represented by the following general formulas (II-6a) to (II-6r).

[0120]

[Chemical Formula 50]



[0121]

The respective compounds are used after sufficient purification by removing impurities using a means such as distillation, column purification, recrystallization or the like.

[0122]

In more detail, if a general liquid crystal composition is prepared, the following compounds are preferably used as the liquid crystal component B and the effects of the present

invention can be obtained by using the liquid crystal component B with the liquid crystal component A.

[0123]

(II-ai): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, in the general formulas (II-1) to (II-4). Specific compounds are compounds having the basic structures of the general formulas (II-1a) to (II-4g) in which the side chain groups are (I-5ah) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r), and preferably compounds having the basic structures of the general formulas (II-1a) to (II-1l) and (II-2i) to (II-2ae), thus obtaining more improved electro-optical characteristics of STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like.

(II-aii): Compounds in which  $X^1$  is F, Cl, or  $-OCF_3$ , in the general formulas (II-1) to (II-4). Specific compounds are compounds having the basic structures of the general formulas (II-1a) to (II-4g) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6d) to (II-6i) and (II-6m) to (II-6o), and preferably compounds having the basic structures of the general formulas (II-1a) to (II-1l), (II-2f) to (II-2q), (II-2u) to (II-2w) and (II-2ab) to (II-4f). If these compounds are used practically as a principal component, the resulting liquid crystal is superior in reduction in driving voltage and high voltage holding ratio of active TFT-LCD, STN-LCD, PDLC and PN-LCD. If these compounds are used in

combination with compounds in which  $X^1$  is F and CN and the both are used practically as a principal component, it becomes possible to obtain excellent electro-optical characteristics such as driving voltage, sharpness, response characteristics and temperature characteristics of TN-LCDs, STN-LCDs, PDLCs, PN-LCDs or the like.

[0124]

(II-aiii): Compounds in which  $Z^5$  is  $-(CH_2)_2-$  or  $-(CH_2)_4-$ , in the general formula (II-1). Specific compounds are compounds having the basic structures of the general formulas (II-1c), (II-1d), (II-1g) and (II-1h) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

(II-aiv): Compounds in which  $k^3$  is 1, in the general formula (II-1). Specific compounds are compounds having the basic structures of the general formulas (II-1e) to (II-1l) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r). These compounds are suited for applications requiring low driving voltage and comparatively small birefringent index.

[0125]

(II-av): Compounds in which at least one of  $Y^3$ ,  $Y^4$ ,  $W^1$  and  $W^2$  is F, in the general formula (II-2). Specific compounds are compounds having the basic structures of the general formulas (II-2a), (II-2c), (II-2f), (II-2i), (II-2l), (II-2o), (II-2r),



(II-2u), (II-2x), (II-2y), (II-2ab) and (II-2ac) in which the side chain groups are (I-5a) to (I-5bc) and the partial structure of the polar group are represented by the general formulas (II-6b), (II-6c), (II-6e), (II-6f), (II-6h), (II-6i), (II-6k), (II-6l), (II-6n), (II-6o), (II-6q) and (II-6r), or compounds having the basic structures of the general formulas (II-2b), (II-2d), (II-2e), (II-2g), (II-2h), (II-2j), (II-2k), (II-2m), (II-2n), (II-2p), (II-2q), (II-2s), (II-2t), (II-2v), (II-2w), (II-2z), (II-2aa), (II-2ad) and (II-2ae) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r), which are suited for applications to reduce the driving voltage.

(II-avi): Compounds in which  $k^3$  is 1 and  $Z^4$  is  $-C\equiv C-$ , in the general formula (II-2). Specific compounds are compounds having the basic structures of the general formulas (II-2o) to (II-2q) and (II-2ab) to (II-2ae) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r), which are suited for applications requiring low driving voltage and comparatively small birefringent index.

(II-avii): Compounds in which  $Z^5$  is a single bond or  $-(CH_2)_2-$  and  $Z^4$  is  $-COO-$ , in the general formula (II-2). Specific compounds are compounds having the basic structures of the general formulas (II-2l) to (II-2n), (II-2r) to (II-2t) and (II-2y) to (II-2aa) in which the side chain groups are (I-5a) to (I-5bc) and the partial structure of the polar group are

represented by the general formulas (II-6a) to (II-6r), which are suited for applications with low driving voltage.

[0126]

(II-aviii): Compounds in which at least one of  $Y^3$ ,  $Y^4$ , and  $W^1$  to  $W^4$  is F, in the general formula (II-3). Specific compounds are compounds having the basic structures of the general formulas (II-3a), (II-3j), (II-3k), (II-3s), (II-3t) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6b), (II-6c), (II-6e), (II-6f), (II-6h), (II-6i), (II-6k), (II-6l), (II-6n), (II-6o), (II-6q) and (II-6r), or compounds having the basic structures of the general formulas (II-3b) to (II-3i), (II-3l) to (II-3r) and (II-3u) to (II-3x) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r), which are suited for applications to reduce the driving voltage.

(II-aix): Compounds in which  $Z^6$  is  $-C\equiv C-$ , in the general formula (II-3). Specific compounds are compounds having the basic structures of the general formulas (II-3k) to (II-3r) in which the side chain groups are (I-5a) to (I-5bc) and the partial structure of the polar group are represented by the general formulas (II-6a) to (II-6r), which are suited for applications requiring low driving voltage and comparatively small birefringent index.

(II-ax): Compounds in which  $Z^4$  is a single bond or  $-C\equiv C-$  and  $Z^6$  is  $-COO-$ , in the general formula (II-3). Specific compounds

are compounds having the basic structures of the general formulas (II-3j) and (II-3y) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

[0127]

(II-axi): Compounds represented by the general formula (II-4). Specific compounds are compounds having the basic structures of the general formulas (II-4a) to (II-4g) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

[0128]

(II-axii): Compounds in which rings  $A^3$  to  $A^5$  represent trans-1,4-cyclohexylene and at least one of hydrogen atoms of this ring is substituted with a deuterium atom, in the general formulas (II-1), (II-2) and (II-4). Specific compounds are compounds having the basic structures of the general formulas (II-1a) to (II-1l), (II-2i) to (II-2ae) and (II-4f) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

[0129]

A nematic liquid crystal composition containing one, or two or more kinds of compounds selected from compounds shown in these sub-groups (II-ai) to (II-axii) is preferred.

[0130]

For the purpose of obtaining a liquid crystal composition suited for use as TN-LC, STN-LCD or the like, the following compounds are preferably used as the liquid crystal component B. The effects of the present invention can be obtained by using such a liquid crystal component B in combination with the liquid crystal component A.

[0131]

(II-bi): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $X^1$  is -CN, in the general formula (II-1). Specific compounds are compounds having the basic structures of the general formulas (II-1a) to (II-1d) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6c).

(II-bii): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $X^1$  is F or -CN, and  $Y^3$  and  $Y^4$  represent H or F, in the general formula (II-1). Specific compounds are compounds having the basic structures of the general formulas (II-1e) to (II-1l) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6f).

[0132]

(II-biii): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 0,  $X^1$  is -CN, and  $Y^3$ ,  $Y^4$ ,  $W^1$ , and  $W^2$  represent H or F, in the general formula (II-2).

Specific compounds are compounds having the basic structures of the general formulas (II-2a) to (II-2h) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structure of the polar group are represented by the general formulas (II-6a) to (II-6c).

(II-biv): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^5$  is a single bond,  $-(CH_2)_2-$ , or  $-COO-$ ,  $Z^4$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ ,  $X^1$  is F or  $-CN$ , and  $Y^3$ ,  $Y^4$ ,  $W^1$ , and  $W^2$  represent H or F, in the general formula (II-2). Specific compounds are compounds having the basic structures of the general formulas (II-2i) to (II-2ae) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structure of the polar group are represented by the general formulas (II-6a) to (II-6f).

[0133]

(II-bv): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, and one of  $Z^4$  and  $Z^6$  is a single bond and other one is a single bond,  $-COO-$ , or  $-C\equiv C-$ , in the general formula (II-3). Specific compounds are compounds having the basic structures of the general formulas (II-3a) to (II-3x) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

(II-bvi): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms and  $Y^3$ ,  $Y^4$ , and  $W^1$  to  $W^4$  represent H

or F, in the general formula (II-3). Specific compounds are compounds having the basic structures of the general formulas (II-3a) to (II-3x) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

[0134]

(II-bvii): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 7 carbon atoms and  $k^4+k^5=0$ , in the general formula (II-4). Specific compounds are compounds having the basic structures of the general formula (II-4a) in which the side chain groups are (I-5a) to (I-5f), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structures of the polar group are (II-6a) to (II-6r).

[0135]

(II-bviii): Compounds in which rings  $A^3$  and  $A^4$  represent trans-1,4-cyclohexylene and at least one hydrogen atom of this ring is substituted with a deuterium atom, in the general formulas (II-1) and (II-2). Specific compounds are compounds having the basic structures of the general formulas (II-1a) to (II-1l) and (II-2i) to (II-2ae) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

[0136]

Preferred is a nematic liquid crystal composition containing one, or two or more kinds of compounds selected

from compounds shown in these sub-groups (II-bi) to (II-bviii), the content of the compounds as the liquid crystal component B being within a range from 10 to 100% by weight.

[0137]

For the purpose of obtaining a liquid crystal composition suited for use as STN-LCD requiring high reliability as well as active TFT-LCD, IPS, STN-LCD, PDLC, PN-LCD or the like, the following compounds are preferably used as the liquid crystal component B. The effects of the present invention can be obtained by using such a liquid crystal component B in combination with the liquid crystal component A.

[0138]

(II-ci): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1, one of  $Z^4$  and  $Z^5$  is a single bond and other one is a single bond,  $-COO-$ ,  $-(CH_2)_2-$ , or  $-(CH_2)_4$ ,  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$ , and one or two of  $Y^3$  and  $Y^4$  represent F, in the general formula (II-1). Specific compounds are compounds having the basic structures of the general formulas (II-1e) to (II-1k) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6d) to (II-6r).

[0139]

(II-cii): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^5$  is a single bond,  $-(CH_2)_2-$ , or  $-COO-$ ,  $Z^4$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ ,  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$ , one or two of  $Y^3$  and  $Y^4$

represent F, and  $W^1$  and  $W^2$  represent H or F, in the general formula (II-2). Specific compounds are compounds having the basic structures of the general formulas (II-2i) to (II-2ae) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6d) to (II-6r).

[0140]

(II-ciii): Compounds in which  $R^1$  is an alkyl or alkenyl group having 2 to 5 carbon atoms, one of  $Z^4$  and  $Z^6$  is a single bond and other one is a single bond,  $-COO-$ , or  $-C\equiv C-$ ,  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$ , one or two of  $Y^3$  and  $Y^4$  represent F, and  $W^1$  to  $W^4$  represent H and one or more of  $W^1$  to  $W^4$  represent F, in the general formula (II-3). Specific compounds are compounds having the basic structures of the general formulas (II-3a) to (II-3x) in which the side chain groups are (I-5a) to (I-5d), (I-5ah) to (I-5am) and (I-5av) to (I-5bc) and the partial structured of the polar group are represented by the general formulas (II-6e), (II-6f), (II-6h), (II-6i), (II-6k), (II-6l), (II-6n), (II-6o), (II-6q) and (II-6r).

[0141]

(II-civ): Compounds in which rings  $A^3$  and  $A^4$  represent trans-1,4-cyclohexylene and at least three hydrogen atoms of this ring are substituted with a deuterium atom, in the general formulas (II-1) and (II-2). Specific compounds are compounds having the basic structures of the general formulas (II-1a) to (II-1l) and (II-2i) to (II-2ae) in which the side chain groups



are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r).

[0142]

Preferred is a nematic liquid crystal composition containing one, or two or more kinds of compounds selected from compounds shown in these sub-groups (II-ci) to (II-civ), the content of the compounds as the liquid crystal component B being within a range from 10 to 100% by weight.

[0143]

Particularly preferred mode in compounds represented by the general formulas (II-1) to (II-4) includes the liquid crystal component B containing the following compounds.

(II-di): Compounds in which  $R^1$  is an alkyl group having 2 to 7 carbon atoms, in the general formulas (II-1) to (II-4).

Compounds in which  $R^1$  is an alkenyl group of  $C_pH_{2p+1}-CH=CH-(CH_2)_q$  (p is 0, 1, 2, or 3, q is 0 or 2), in the general formulas (II-1) and (II-2). Specifically, compounds having the basic structures of the general formulas (II-1a), (II-1e), (II-2a), (II-2c), (II-2d), (II-2i), (II-2l), (II-2o), (II-3a), (II-3l), (II-4a) to (II-4c) and (II-4e) have preferably these groups, and the viscosity and viscoelasticity can be reduced when the liquid crystal component B contains at least one compound having an alkyl or alkenyl group.

(II-dii): It is preferred that the liquid crystal component B contains at least one compound in which  $X^1$  is F, Cl,  $-OCF_3$ , or  $-CN$  in the general formulas (II-1) to (II-4) after selection.

(II-diii): If high-speed response is considered to be important, compounds of the general formulas (II-1a), (II-1e), (II-2a), (II-2c), (II-2d), (II-2i), (II-2l), (II-2o), (II-3a), (II-3l) and (II-4a) in which  $X^1$  is F,  $-OCF_3$ , or  $-CN$  in the general formulas (II-1) to (II-4) are preferably used in a large amount based on the crystal liquid component B.

(II-div): If larger birefringent index is required, compounds of the general formulas (II-2a) to (II-4d) in which  $X^1$  is Cl,  $-OCF_3$ , or  $-CN$  in the general formulas (II-2) to (II-4) and compounds of the general formulas (II-2f) to (II-2h), (II-2o) to (II-2q), (II-2ab) to (II-2ae) and (II-3k) to (II-3x) in which  $Z^4$  and  $Z^6$  represent  $-C\equiv C-$  in the general formulas (II-2) and (II-3) are preferably used in a large amount based on the crystal liquid component B.

(II-dv): If lower driving voltage is required, compounds of the general formulas (II-1a) to (II-4g) in which  $X^1$  is F, Cl, or  $-CN$  and one of a pair of  $Y^3$  and  $Y^4$  is necessarily F in the general formulas (II-1) to (II-4) are preferably used in a large amount based on the crystal liquid component B.

(II-dvi): Although compounds in which hydrogen atoms in the cyclohexane ring of the general formulas (II-1) and (II-2) are substituted with a deuterium atom, these compounds are useful to adjust the elastic constant of the liquid crystal composition and to adjust the pre-tilt angle corresponding to the alignment film. Therefore, the liquid crystal component B preferably contains at least one compound substituted with a deuterium atom.

(II-dvii): A mixing ratio of the component "dicyclized compound in which  $k^3$  to  $k^5$  represent 0 in the general formulas (II-1), (II-2) and (II-4)" to the component "compound in which  $k^3$  is 1 in the general formulas (II-1) and (II-2), compound in which  $k^4+k^5=1$  in the general formula (II-4) and/or tricyclized compound of the general formula (II-3)" can be appropriately selected within a range from 0 to 100 (100 to 0). If higher nematic phase-isotropic liquid phase transition temperature is required, "compound in which  $k^3$  is 1 in the general formulas (II-1) and (II-2), compound in which  $k^4+k^5=1$  in the general formula (II-4) and/or tricyclized compound of the general formula (II-3)" are preferably used in a large amount based on the crystal liquid component B.

[0144]

Preferred is a nematic liquid crystal composition containing one, or two or more kinds of compounds selected from compounds shown in these sub-groups (II-di) to (II-dvii), the content of the compounds as the liquid crystal component B being within a range from 10 to 100% by weight.

[0145]

The liquid crystal component B containing these compounds (II-ai) to (II-dvii) has a feature that it can be well mixed with the liquid crystal component A as an essential component, and is particularly useful for preparation according to the purpose of the driving voltage, improvement in temperature dependency and improvement in response characteristics. Particularly, compounds of the general formulas (II-1a) to

(II-1g), (II-2a) to (II-2q), (II-2u) to (II-2x), (II-2ab) to (II-2ae), (II-3a) to (II-3d), (II-3l) to (II-3r) and (II-4a) to (II-14e) are superior in at least one of individual effects and this effect can be obtained even in the case of small content within a range from 0.1 to 25% by weight based on the total amount of the nematic liquid crystal composition of the present invention.

[0146]

Although the liquid crystal component B of the present invention can contain at least one compound selected from one, two, or three or more sub-groups among these sub-groups (II-ai) to (II-dvii), the effect can be obtained by composing of only one compound from one sub-group. Compounds capable of having two or more structural features of compounds shown in the sub-groups (II-ai) to (II-dvii) are more preferred. The liquid crystal component B can be composed of compounds shown in the above sub-groups (II-ai) to (II-dvii) according to the desired purposes.

[0147]

The liquid crystal composition of the present invention, which is obtained by using a liquid crystal component B containing, as a principal component, compounds of the general formulas (II-1) to (II-4) related to the liquid crystal composition of the present invention, or a liquid crystal component B containing compounds of the above-described sub-groups (II-ai) to (II-dvii), or a liquid crystal component B capable of having two or more structural features of the same

groups (II-ai) to (II-dvii) in combination with a liquid crystal component A broadens the operating temperature range of liquid crystal display characteristics due to an improvement in co-solubility and storage at low temperature, thereby making it possible to improve a reduction in driving voltage and a change in temperature and to attain comparatively fast response characteristics for a predetermined driving voltage, thus obtaining more improved electro-optical characteristics of TN-LCDs, STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like using the liquid crystal composition as a constituent material.

[0148]

High-reliability STN-LCD as well as active STN-LCD, TFT-LCD, PDLC and PN-LCD are preferably composed of compounds free from nitrogen and oxygen atoms. From such a point of view, it is preferred to contain, as the liquid crystal component A, 50 to 100% by weight of compounds in which  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$ ,  $Y^1$  and  $Y^2$  represent H, F, Cl,  $CF_3$ , or  $OCF_3$ , and  $Z^1$  to  $Z^3$  represent a single bond,  $-CH=CH-$ ,  $-C\equiv C-$ ,  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ ,  $-CH=CH-(CH_2)_2-$ , or  $-(CH_2)_2-CH=CH-$  in the general formulas (I-1) to (I-4). When using in combination with the liquid crystal component B, it is preferred to contain, as the liquid crystal component B, 50 to 100% by weight of compounds in which  $X^1$  is F, Cl,  $CF_3$ ,  $OCF_3$ , or  $OCF_2H$ ,  $Y^3$  and  $Y^4$  represent H, F, Cl,  $CF_3$ , or  $OCF_3$ , and  $Z^4$  to  $Z^6$  represent a single bond,  $-CH=CH-$ ,  $-C\equiv C-$ ,  $-(CH_2)_2-$ ,  $-(CH_2)_4-$ ,  $-CH=CH-(CH_2)_2-$ ,

or  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$  in the general formulas (II-1) to (II-4). It is particularly preferred to contain 50 to 100% by weight of compounds selected from the above-described sub-groups (II-ci) to (II-civ).

[0149]

In the case of high-reliability STN-LCD, the sum total of the liquid crystal component A and the liquid crystal component B is preferably within a range from 10 to 100% by weight, more preferably from 30 to 100% by weight, and still more preferably from 60 to 100% by weight. In this case, a relative mixing ratio of the liquid crystal component A to the liquid crystal component B can be selected from a range of 100:0 to 0.1:99.9, and preferably from a range of 100:0 to 5:95, and more preferably selected from a range of 100:0 to 10:90. In the case of active STN-LCD, TFT-LCD, PDLC and PN-LCD, the sum total of the liquid crystal component A and the liquid crystal component B is preferably within a range from 20 to 100% by weight, more preferably from 40 to 100% by weight, and still more preferably from 60 to 100% by weight. In this case, a relative mixing ratio of the liquid crystal component A to the liquid crystal component B can be selected from a range of 100:0 to 0.1 to 99.9, preferably 100:0 to 5:95, and is more preferably selected from a range of 100:0 to 90:10, range of 90:10 to 70:30, range of 70:30 to 40:60, range of 40:60 to 20:80 and range of 20:80 to 5:95, according to the purposes.

[0150]

Active STN-LCD is developed to obtain higher contrast at a wide viewing angle and to improve the response time of last transition, and enables STN-LCD to perform active driving using the technique of TFT and MIM.

[0151]

The effect of the liquid crystal component A and liquid crystal component B can also be obtained even if the content of a liquid crystal component C described below is very small. For the purpose of particularly reducing the driving voltage, the content of a liquid crystal component C can be adjusted to 10% by weight or less. In this case, the viscosity of the liquid crystal component C is preferably reduced as small as possible so that the driving voltage is less likely to increase, thereby efficiently improving the response time. For example, the content of the liquid crystal component C is small, the method of attaining this effect by the liquid crystal component B is that the liquid crystal component B preferably contains any of compounds in which  $X^1$  is F, Cl,  $-OCF_3$ , or  $-CN$  in the general formulas (II-1) to (II-4), compounds in which  $Y^3$  to  $Y^4$  represent F in the general formulas (II-1) to (II-4), compounds in which  $Z^4$  is a single bond,  $-COO-$ , or  $-C\equiv C-$  in the general formulas (II-2) and (II-3) and compounds in which  $k^3$  is 0 in the general formula (II-1). Particularly, compounds in which  $X^1$  is F or  $-CN$  in the general formulas (II-1) to (II-4) and/or compounds in which  $Y^3$  and  $Y^4$  represent F in the general formulas (II-1) to (II-4) are preferred.

[0152]

The liquid crystal composition of the present invention preferably contains 85% by weight or less of the liquid crystal component C having a dielectric constant anisotropy within a range from -10 to 2, in addition to the liquid crystal component A as an essential component. Preferred examples of the liquid crystal component having a dielectric constant anisotropy within a range from -10 to 2 are as follows. That is, it is a compound which has a bar-like chemical structure, the center portion having a core structure with one to four six-membered rings, the six-membered ring positioned at both terminals in the major axis direction of the center portion having a terminal group substituted at the position corresponding to the direction of the major axis of the liquid crystal, the both of terminal groups, which are present at both terminals, being a non-polar group, for example, alkyl group, alkoxy group, alkoxyalkyl group, alkenyl group, alkenyloxy group, alkanoyloxy group or the like. The liquid crystal composition of the present invention is preferably composed of one to forty kinds, and more preferably two to twenty kinds of the liquid crystal component.

[0153]

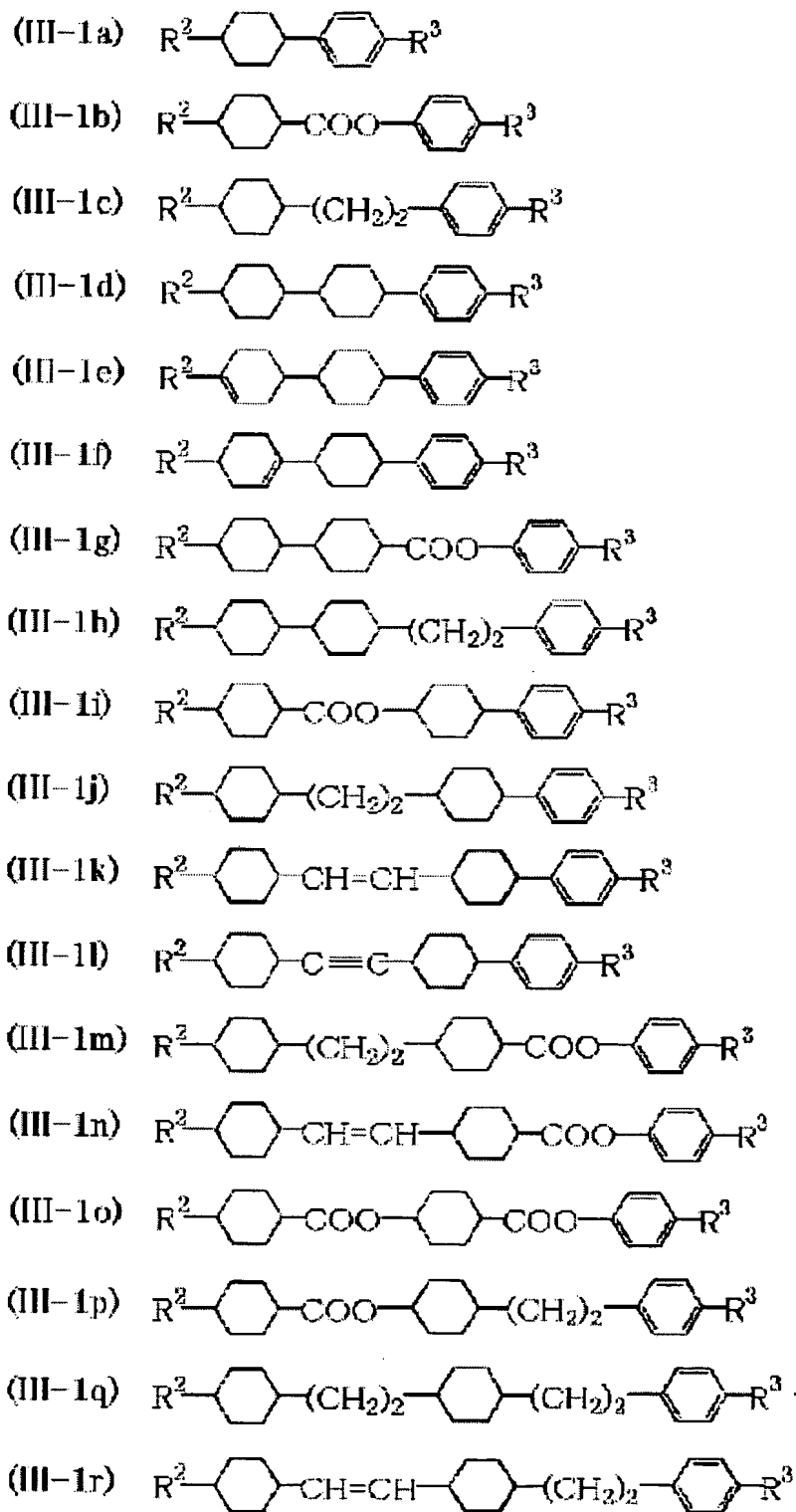
From such a point of view, more preferred mode of the basic structure in compounds represented by the general formulas (III-1) to (III-4) includes compounds represented by the general formulas (III-1a) to (III-4o). The liquid crystal composition preferably contains 10 to 100% by weight of



compounds selected from compounds represented by the general formulas (III-1) to (III-4) as the liquid crystal component C of the present invention. The liquid crystal component C containing these compounds has a feature that it can be well mixed with the liquid crystal component A containing compounds of the general formulas (I-1) to (I-4), and is particularly useful to improve the nematic phase at low temperature, and also can adjust the desired birefringent index and improve the sharpness, response characteristics and temperature characteristics thereof of TN-LCDs, STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like.

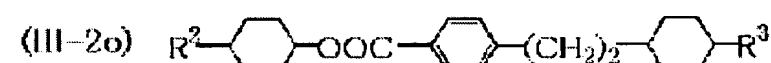
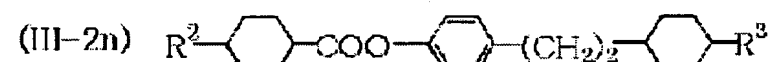
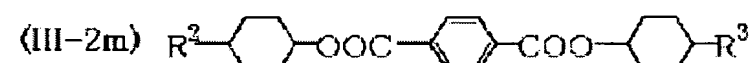
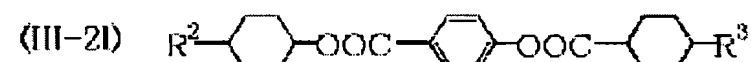
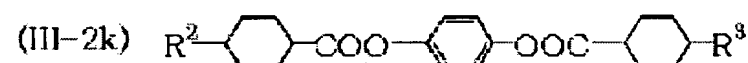
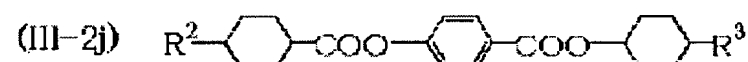
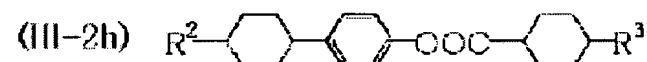
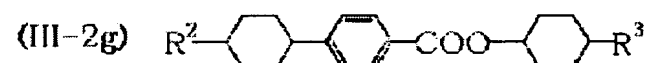
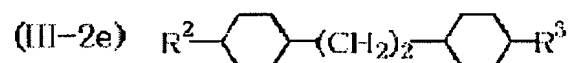
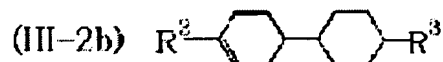
[0154]

[Chemical Formula 51]



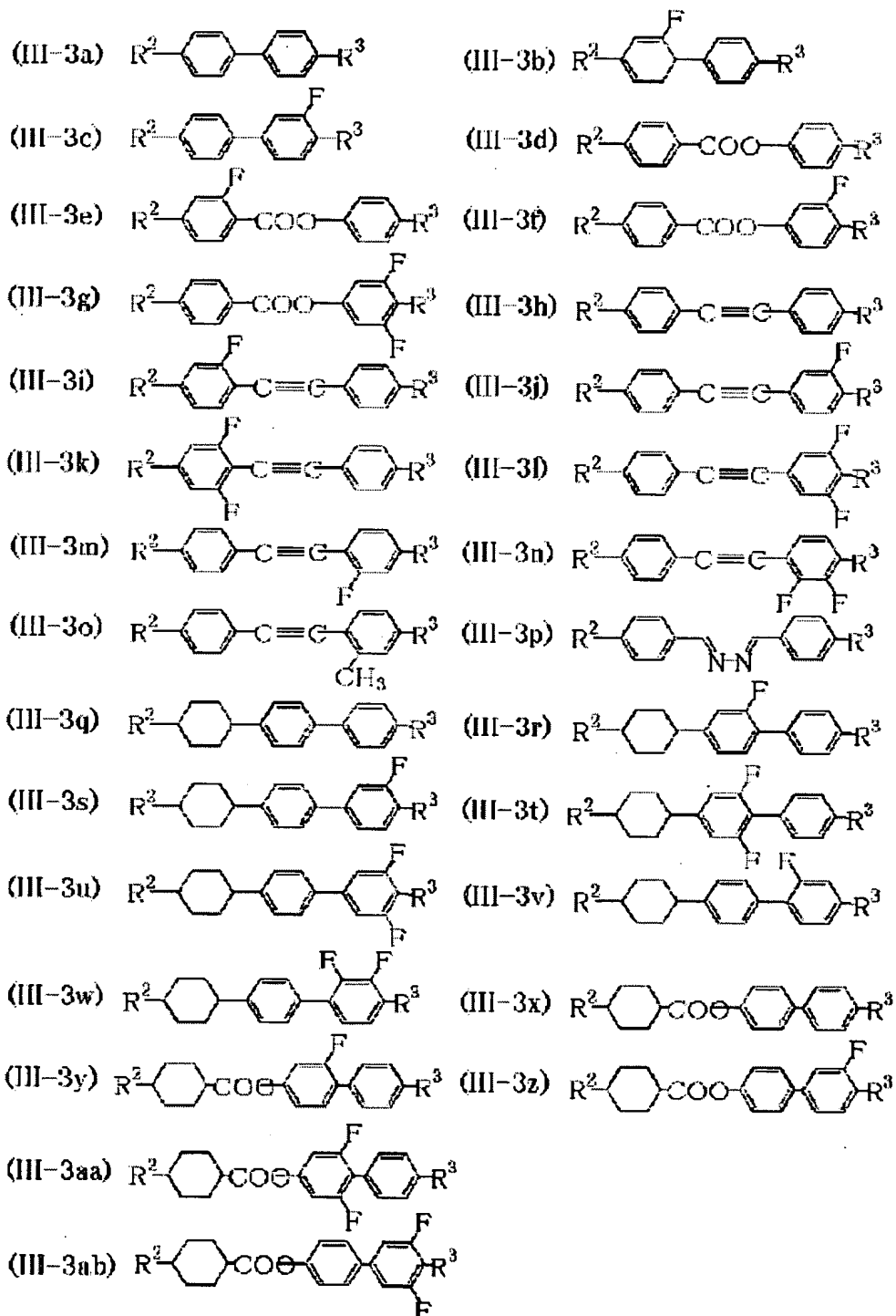
[0155]

[Chemical Formula 52]



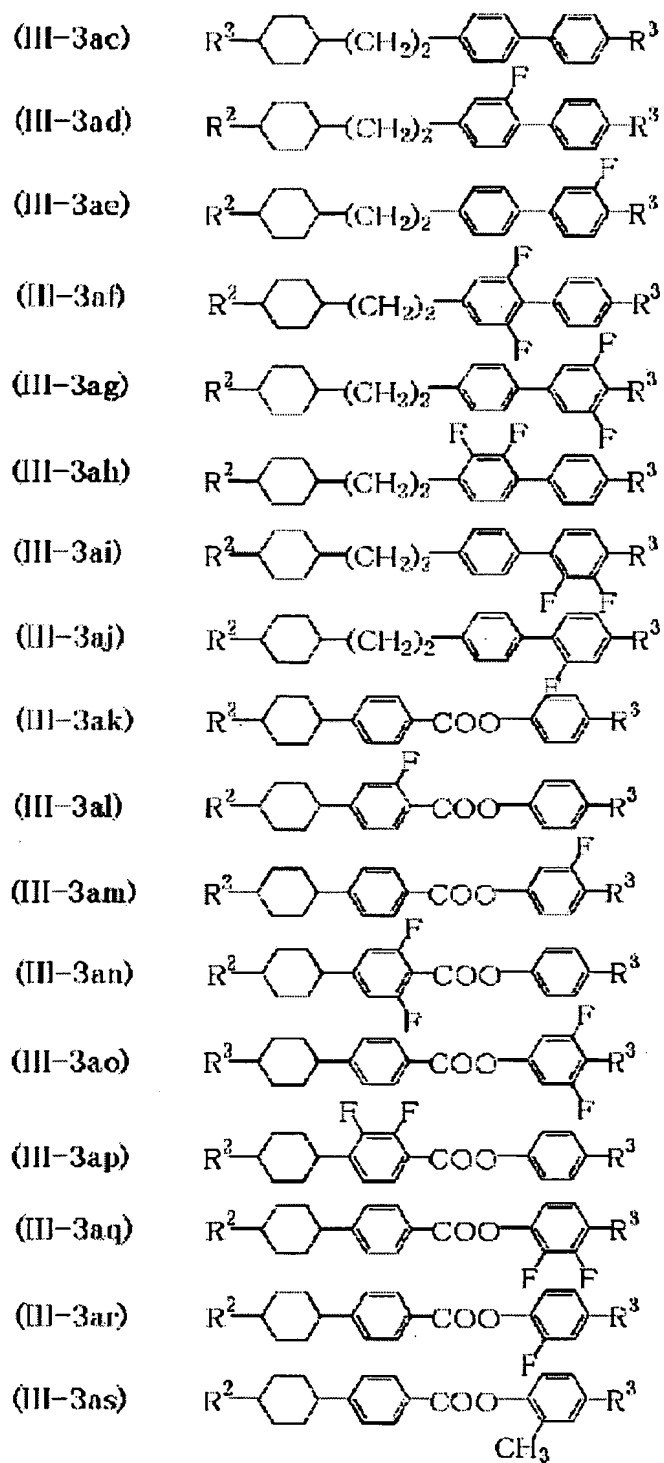
[0156]

[Chemical Formula 53]



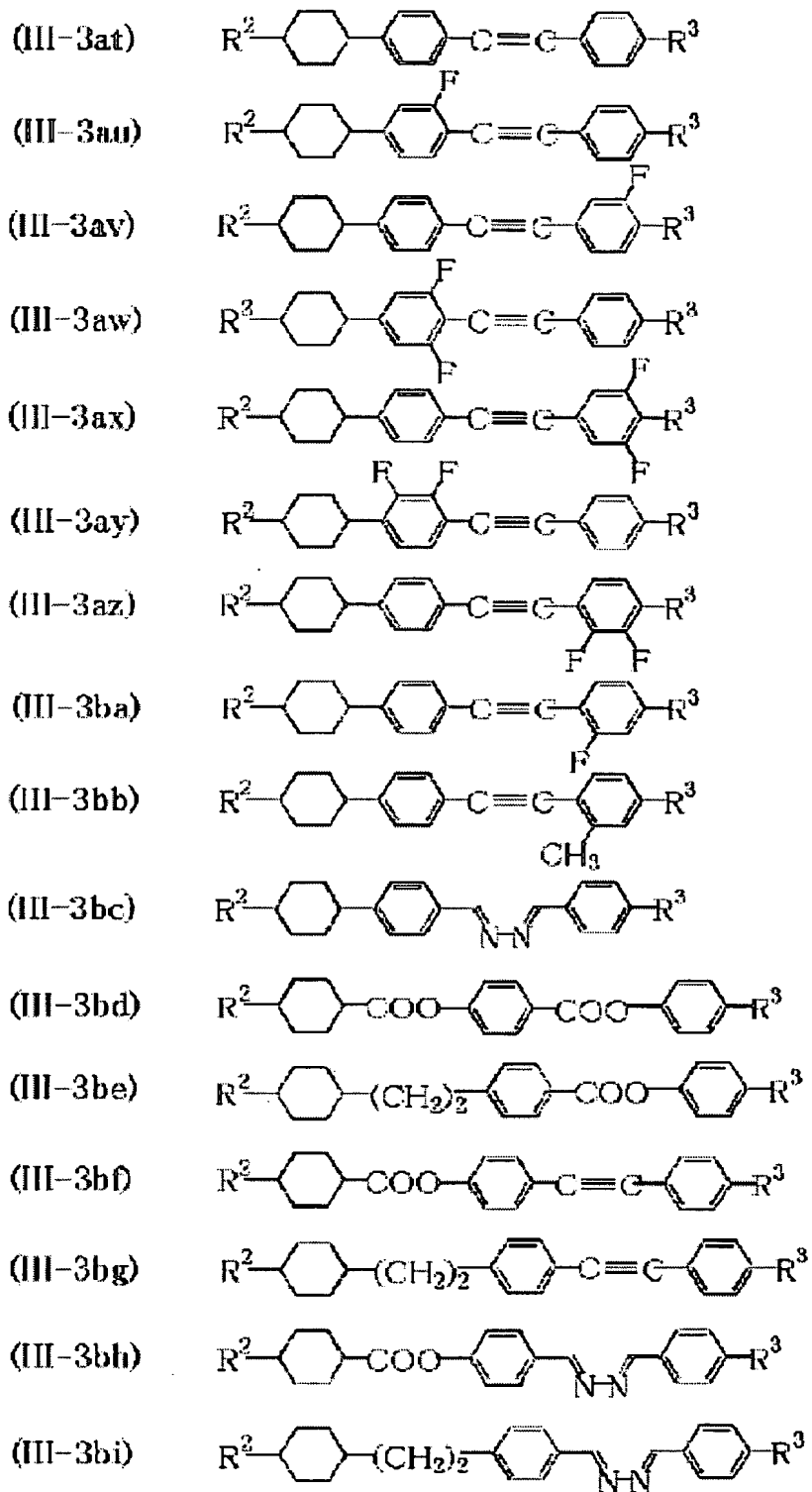
[0157]

[Chemical Formula 54]



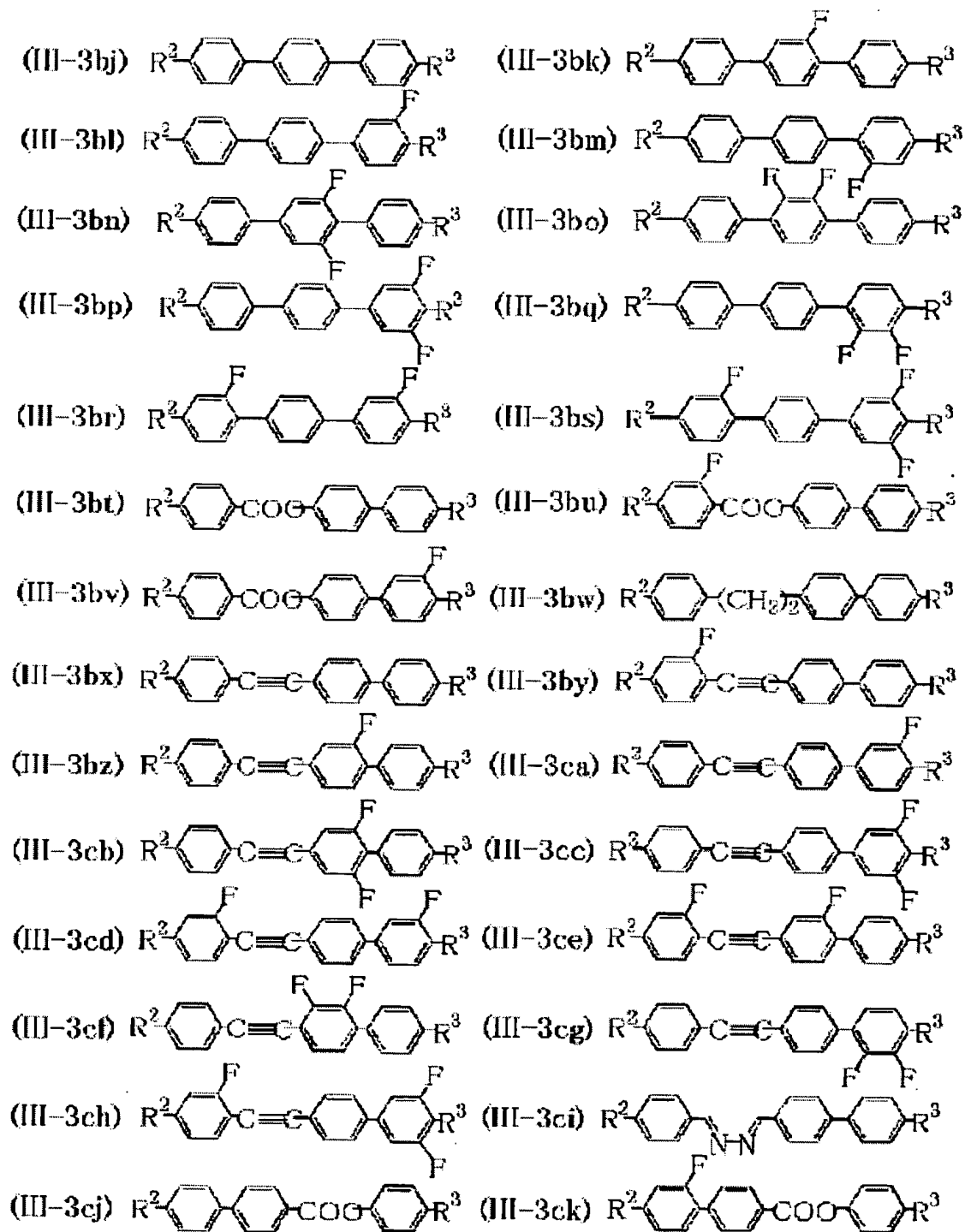
[0158]

[Chemical Formula 55]



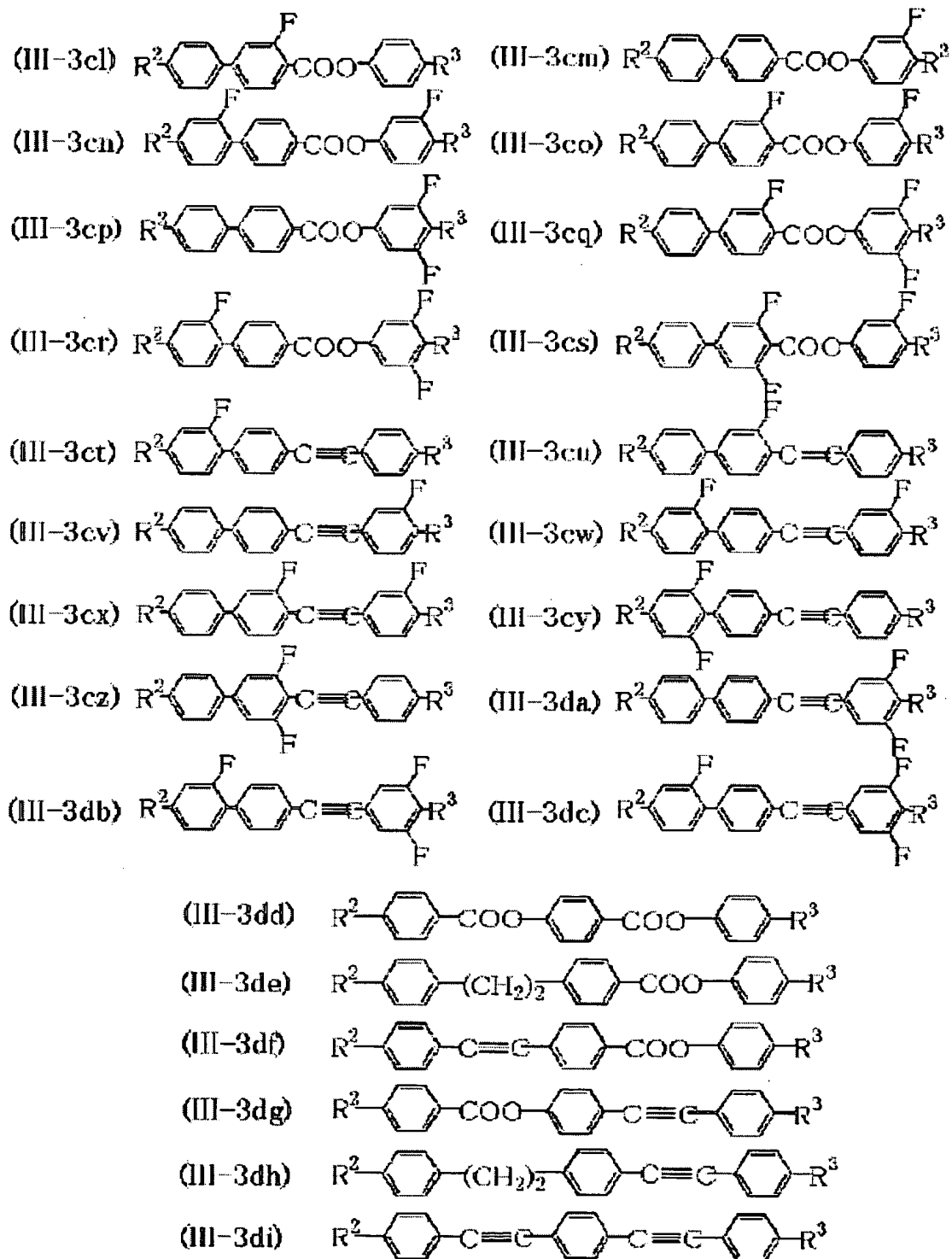
[0159]

[Chemical Formula 56]



[0160]

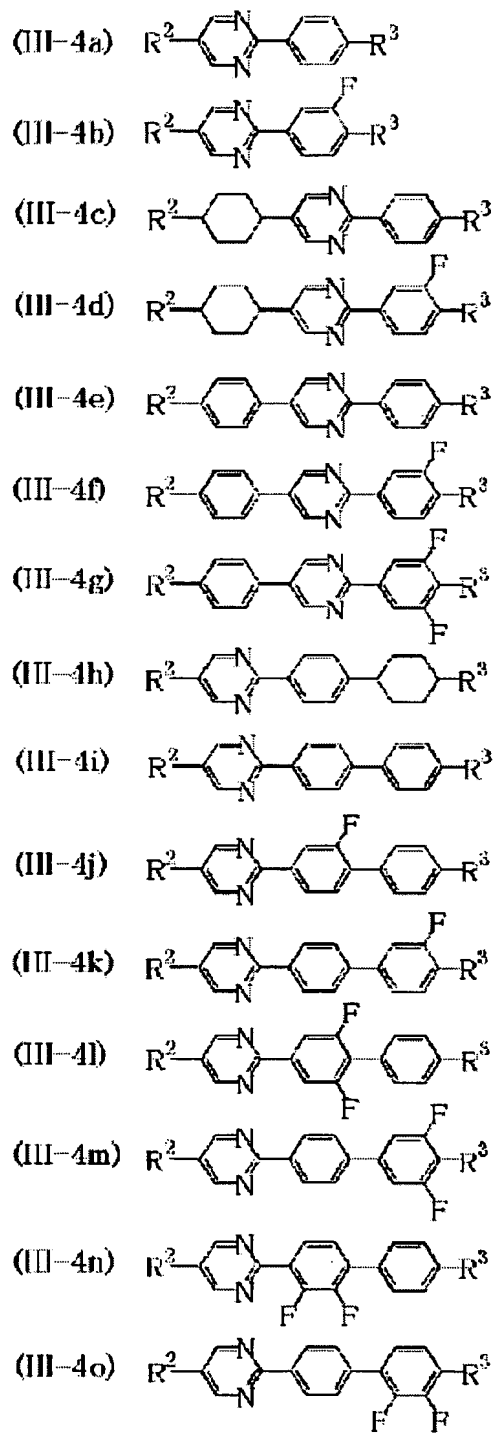
[Chemical Formula 57]





[0161]

[Chemical Formula 58]

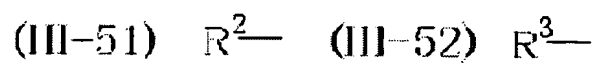


[0162]

More preferred mode of the formulas (III-51) and (III-52):

[0163]

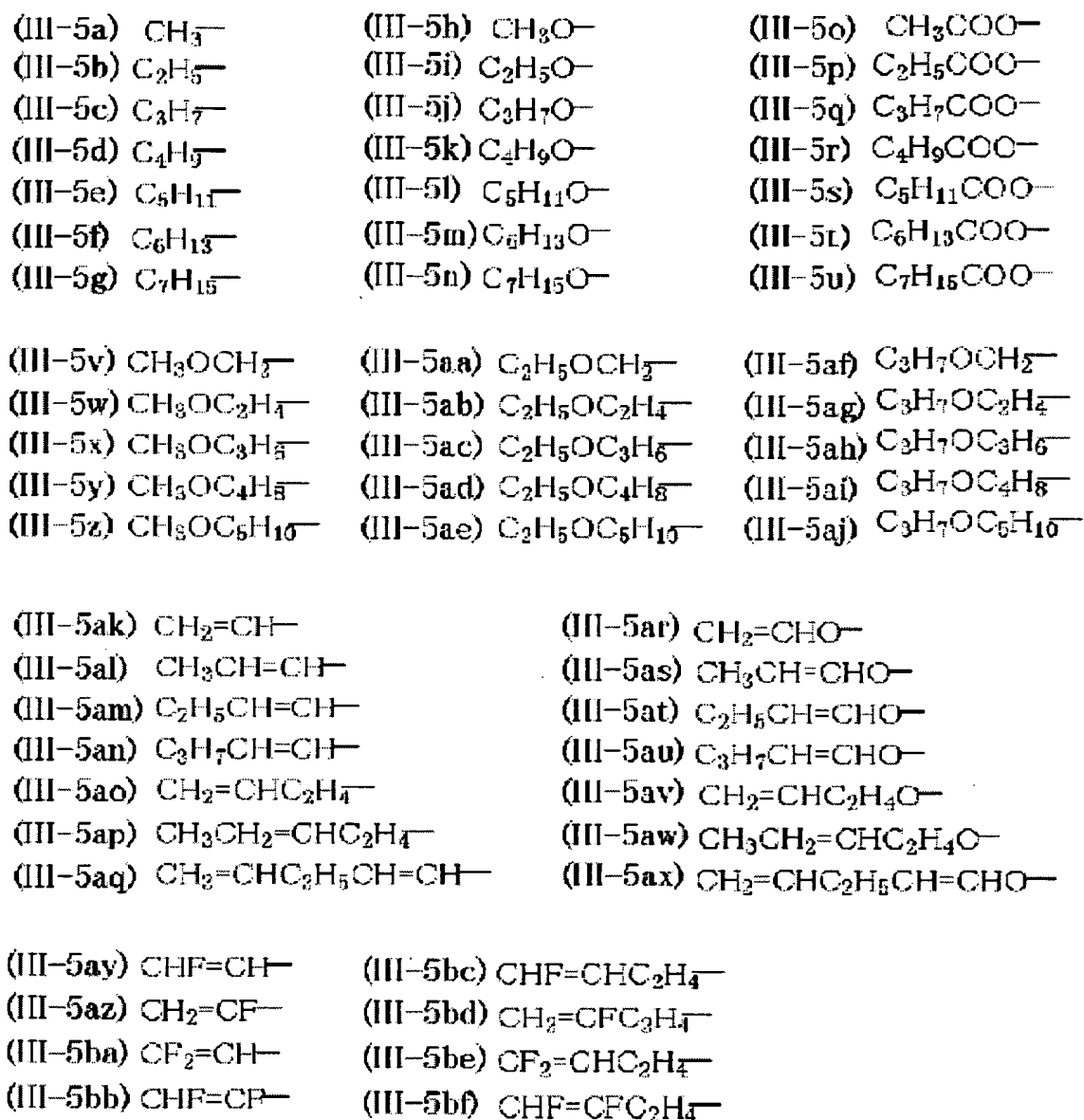
[Chemical Formula 59]



in side chain groups  $R^2$  and  $R^3$  are compounds represented by the general formulas (III-5a) to (III-5bf) described below.

[0164]

[Chemical Formula 60]



[0165]

The respective compounds are used after sufficient purification by removing impurities using a means such as distillation, column purification, recrystallization or the like.

[0166]

The liquid crystal component C can contain compounds represented by the general formulas (III-1) to (III-4), but may be composed of compounds represented by the general formula (III-1), compounds represented by the general formula (III-2), compounds represented by the general formula (III-3), compounds represented by the general formula (III-4), or a combination thereof. More preferably, the nematic liquid crystal composition contains the liquid crystal component C containing one, or two or more kinds of compounds selected from compounds represented by the general formulas (III-1) to (III-3), the content of the compounds being within a range from 10 to 100% by weight.

[0167]

In more detail, if a general liquid crystal composition is prepared, the following compounds are preferably used as the liquid crystal component C, and the effects of the present invention can be obtained by using the liquid crystal component C in combination with the liquid crystal component A or B.

[0168]

(III-ai): Compounds in which  $R^2$  is an alkenyl group having 2

to 5 carbon atoms, in the general formulas (III-1) to (III-4), and specifically compounds having the basic structures of the general formulas (III-1a) to (III-4o) in which side chain group  $R^3$  represents (III-5a) to (II-5bf) and side chain group  $R^2$  represents (III-5ak) to (II-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf), which improve the response characteristics by a reduction in viscosity and viscoelasticity and improve the nematic phase-isotropic liquid phase transition temperature, thus obtaining more improved electro-optical characteristics of TN-LCDs, STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like.

(III-aii): Compounds in which  $R^3$  is a straight-chain alkenyl or alkenyloxy group having 2 to 7 carbon atoms, in the general formulas (III-1) to (III-4), and specifically compounds having the basic structures of the general formulas (III-1a) to (III-4o) in which the side chain group  $R^2$  represents (III-5a) to (II-5bf) and the side chain group  $R^3$  represents (III-5ak) to (III-5bf), which improve the response characteristics by a reduction in viscosity and viscoelasticity and improve the nematic phase-isotropic liquid phase transition temperature, thus obtaining more improved electro-optical characteristics of TN-LCDs, STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like.

[0169]

(III-aiii): Compounds in which  $k^3$  is 0 and  $Z^5$  is a single bond or  $-(CH_2)_2-$ , in the general formula (III-1), and specifically compounds having the basic structures of the general formulas (III-1a) and (III-1c) in which side chain groups  $R^2$  and  $R^3$  are

(III-5a) to (III-5bf).

(III-aiv): Compounds in which  $k^3$  is 1, in the general formula (III-1), and specifically compounds having the basic structures of the general formulas (III-1d) to (III-1r) in which side chain groups  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

[0170]

(III-av): Compounds represented by the general formula (III-2), and specifically compounds having the basic structures of the general formulas (III-2a) to (III-2o) in which  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

[0170]

(III-avi): Compounds in which at least one of  $Y^5$ ,  $Y^6$ , and  $W^1$  to  $W^3$  is F, in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3b), (III-3c), (III-3e), (III-3g), (III-3i) to (III-3l), (III-3n), (III-3r) to (III-3u), (III-3w), (III-3y) to (III-3ab), (III-3ad) to (III-3ai), (III-3al) to (III-3aq), (III-3au) to (III-3az), (III-3bk), (III-3bl), (III-3bn) to (III-3bs), (III-3bu), (III-3bv), (III-3by) to (III-3ch) and (III-3ck) to (III-3dc) in which side chain groups  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

(III-avii): Compounds in which  $Y^7$  is F or  $-CH_3$ , in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3m) to (III-3o), (III-3v), (III-3w), (III-3ai), (III-3aj), (III-3aq) to (III-3as), (III-3az) to (III-3bb), (III-3bm), (III-3bq) and (III-3cg) in which side chain groups  $R^2$  and  $R^3$  (III-5a) to (III-5bf).

(III-aviii): Compounds in which  $k^3$  is 0 and  $Z^6$  is a single bond, in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3a) to (III-3c) in which side chain groups  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

(III-aix): Compounds in which  $k^3$  is 1 and  $Z^4$  is a single bond,  $-\text{OCO}-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_4-$ ,  $-\text{CH}=\text{CH}-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{N}-$ ,  $-\text{CH}=\text{N}-\text{N}=\text{CH}-$ ,  $-\text{N}(\text{O})=\text{N}-$ ,  $-\text{CH}=\text{CH}-$ , or  $-\text{CF}=\text{CF}-$ , in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3q) to (III-3w), (III-3ac) to (III-3bc), (III-3be), (III-3bg), (III-3bi) to (III-3bs), (III-3bw), (III-3ci) to (III-3dc), (III-3de) and (III-3dh) in which side chain groups  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

(III-ax): Compounds in which  $Z^4$  is  $-\text{COO}-$  or  $-\text{C}\equiv\text{C}-$  and  $Z^6$  is  $-\text{OCO}-$ ,  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_4-$ ,  $-\text{CH}=\text{CH}-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{N}-$ ,  $-\text{CH}=\text{N}-\text{N}=\text{CH}-$ ,  $-\text{N}(\text{O})=\text{N}-$ ,  $-\text{CH}=\text{CH}-$ ,  $-\text{CF}=\text{CF}-$ , or  $-\text{C}\equiv\text{C}-$ , in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3bf), (III-3bh), (III-3df) and (III-3dg) in which side chain groups  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

[0172]

(III-axi): Compounds represented by the general formula (III-4), and specifically compounds having the basic structures of the general formulas (III-4a) to (III-4o) in which side chain

groups  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

[0173]

(III-axii): Compounds selected from compounds in which rings  $A^3$ ,  $A^6$  and  $A^7$  represent trans-1,4-cyclohexylene and at least one of hydrogen atoms of these rings is substituted with a deuterium atom, in the general formulas (III-1) to (III-4), and specifically compounds having the basic structures of the general formulas (III-1a) to (III-2o), (III-3q) to (III-3bi), (III-4c), (III-4d) and (III-4h) in which side chain groups  $R^2$  and  $R^3$  are (III-5a) to (III-5bf).

[0174]

A nematic liquid crystal composition containing one, or two or more kinds of compounds selected from compounds shown in these sub-groups (III-ai) to (III-axii) is preferred.

[0175]

Preferred mode in compounds represented by the general formulas (III-1) to (III-4) is a liquid crystal component C containing the following compounds.

[0176]

(III-bi): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $Z^5$  is a single bond,  $-COO-$ , or  $-(CH_2)_2-$ , in the general formula (III-1), and specifically compounds having the basic structures of the general formulas (III-1a) to (III-1c) in which the side chain group  $R^2$  represents (III-5a) to (III-5e)



and (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

(III-bii): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1, the ring  $A^6$  is trans-1,4-cyclohexylene, and one of  $Z^4$  and  $Z^5$  is a single bond and other one is a single bond,  $-COO$ , or  $-(CH_2)_2-$ , in the general formula (III-1), and specifically compounds having the basic structures of the general formulas (III-1d), (III-1g) to (III-1j) in which the side chain group  $R^2$  represents (III-5a) to (III-5e) and (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

[0177]

(III-biii): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms, the ring  $A^3$  is trans-1,4-cyclohexylene or trans-1,4-cyclohexenylene,  $k^3$  is 0, and  $Z^5$  is a single bond,  $-COO-$ , or  $-(CH_2)_2-$ , in the general formula (III-2), and specifically compounds having the basic structures of the general formulas (III-2a), (III-2d) and (III-2e) in which the side chain group

$R^2$  represents (III-5a) to (III-5e) and (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

(III-biv): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms, the ring  $A^3$  is trans-1,4-cyclohexylene or trans-1,4-cyclohexenylene,  $k^3$  is 1, and one of  $Z^5$  and  $Z^4$  is a single bond, in the general formula (III-2), and specifically compounds having the basic structures of the general formulas (III-2f) to (III-2i) in which the side chain group  $R^2$  represents (III-5a) to (III-5e) and (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

[0178]

(III-bv): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 0, and  $Z^6$  is a single bond,  $-C\equiv C-$ , or  $-CH=N-N=CH$ , in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3a) to (III-3c) and (III-3h) to (III-3p) in which the side chain group  $R^2$  represents (III-5a) to (III-5e) and (III-5ak) to (III-5ap) and

the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

(III-bvi): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1,  $Z^4$  is a single bond,  $-(CH_2)_2-$ ,  $-COO-$ , or  $-C\equiv C-$ , and  $Z^6$  is a single bond,  $-COO-$ , or  $-C\equiv C-$ , in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3q) to (III-3bb), (III-3bd) to (III-3bg), (III-3bj) to (III-3ch) and (III-3cj) to (III-3di) in which the side chain group  $R^2$  represents (III-5a) to (III-5e) and (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

(III-bvii): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms,  $k^3$  is 1, one of  $Z^4$  and  $Z^6$  is a single bond and other one is a single bond or  $-C\equiv C-$ , and at least one of  $W^1$  and  $W^2$  is F, in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3r), (III-3t), (III-3au), (III-3aw), (III-3ay), (III-3bk), (III-

3bn), (III-3bo), (III-3bz), (III-3cb), (III-3ce), (III-3cf), (III-3cu), (III-3cx) and (III-3cz) in which the side chain group  $R^2$  represents (III-5a) to (III-5e) and (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

(III-bviii): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,  $R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms, and any one of  $Y^6$  and  $Y^7$  is substituted with F or  $CH_3$ , in the general formula (III-3), and specifically compounds having the basic structures of the general formulas (III-3c), (III-3f), (III-3g), (III-3j), (III-3l) to (III-3o), (III-3s), (III-3u) to (III-3w), (III-3z), (III-3ab), (III-3ae), (III-3ag), (III-3ai), (III-3aj), (III-3am), (III-3ao), (III-3aq) to (III-3as), (III-3av), (III-3ax), (III-3az) to (III-3bb), (III-3bl), (III-3bm), (III-3bp) to (III-3bs), (III-3bv), (III-3ca), (III-3cc), (III-3cd), (III-3cg), (III-3ch), (III-3cm) to (III-3cs), (III-3cv) to (III-3cx) and (III-3da) to (III-3dc) in which the side chain group  $R^2$  represents (III-5a) to (III-5e), (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

[0179]

(III-bix): Compounds in which  $R^2$  is an alkyl group having 1 to 5 carbon atoms or an alkenyl group having 2 to 5 carbon atoms,

$R^3$  is an alkyl or alkoxy group having 1 to 5 carbon atoms, or alkenyl or alkenyloxy group having 2 to 5 carbon atoms, and  $k^4+k^5=0$ , in the general formula (III-4), and specifically compounds having the basic structures of the general formulas (III-4a) and (III-4b) in which the side chain group  $R^2$  represents (III-5a) to (III-5e) and (III-5ak) to (III-5ap) and the side chain group  $R^3$  represents (III-5a) to (III-5e), (III-5g) to (III-5l), (III-5ak) to (III-5ap), (III-5ar) to (III-5aw) and (III-5ay) to (III-5bf).

[0180]

Preferred is a nematic liquid crystal composition containing one, or two or more kinds of compounds selected from compounds shown in these sub-groups (III-bi) to (III-bix), the content of the compounds as the liquid crystal component C being within a range from 10 to 100% by weight.

[0181]

Preferred mode in compounds represented by the general formulas (III-1) to (III-4) is a liquid crystal component C containing the following compounds.

[0182]

The liquid crystal composition containing compounds of the general formulas (III-1) to (III-4) as the liquid crystal component C has a feature that it can reduce the viscosity and viscoelasticity, thus leading to comparatively high holding ratio of the resistivity and voltage. The viscosity of the liquid crystal component C is preferably small as possible. In the present invention, the viscosity is preferably 45 cp or

less, more preferably 30 cp or less, still more preferably 20 cp or less, and particularly preferably 15 cp or less. From such a point of view, preferred compounds are compounds (III-ci) having the basic structures represented by the general formulas (III-1a) to (III-1f), (III-1k), (III-2a) to (III-2f), (III-3a), (III-3h) to (III-3j), (III-3o), (III-3p), (III-3q), (III-3ac), (III-3at) to (III-3ax), (III-3ba), (III-3bb), (III-3bf), (III-3bg), (III-3bx) to (III-3cb) and (III-3ct) to (III-3cx),

[0183]

preferably compounds (III-cii) in which  $R^2$  is a straight-chain alkyl group having 2 to 5 carbon atoms or an alkenyl group of  $C_pH_{2p+1}-CH=CH-(CH_2)_q$  ( $p=0, 1, 2, \text{ or } 3$  and  $q=0$  or  $2$ ) and  $R^3$  is a straight-chain alkyl group having 1 to 5 carbon atoms or an alkenyl group of  $C_pH_{2p+1}-CH=CH-(CH_2)_q$  ( $p=0, 1, 2, \text{ or } 3$  and  $q=0$  or  $2$ ) among the compounds (III-ci),

[0184]

and more preferably compounds (III-ciii) having the basic structures represented by the general formulas (III-1a), (III-1d), (III-2a), (III-2f), (III-3a), (III-3h), (III-3p) and (III-3q) in which both side chain groups are alkenyl groups.

[0185]

Although the liquid crystal component C of the present invention can be composed of each of the compounds represented by the general formulas (III-1), (III-2), (III-3) and (III-4) alone, the birefringent index of the liquid crystal composition can be easily optimized according to applications

by using (III-civ): compounds represented by the general formulas (III-1) and/or (III-2), and particularly compounds of the general formulas (III-1a), (III-1d), (III-2a) to (III-2c) and (III-c) in combination with (III-cv): compounds represented by the general formulas (III-3) and/or (III-4), particularly compounds in which  $Z^4$  is a single bond,  $-C\equiv C-$ , or  $-CH=N-N=CH-$  in the general formula (III-3), and specifically compounds of the general formulas (III-3a), (III-3h), (III-3p), (III-3q), (III-3at), (III-4a) and (III-4h)" (III-cv). Generally, the birefringent index can be reduced by using the compounds of the general formulas (III-1) and (III-2), for example, compounds of the general formulas (III-1a) to (III-2f) in a large amount, thereby making it possible to easily attain an reduction in color irregularity of the liquid crystal display device, an improvement in viewing angle characteristics and an increase in contrast ratio. The birefringent index can be enhanced by using the compounds of the general formulas (III-3), for example, compounds of the general formulas (III-3a) to (III-3j), or compounds of the general formulas (III-4), for example, compounds of the general formulas (III-4a) to (III-4e) in a large amount, thereby making it possible to produce a thin liquid crystal display element having a liquid crystal layer having a thickness within a range from 1 to 5  $\mu\text{m}$ .

[0186]

Preferred is a nematic liquid crystal composition containing one, or two or more kinds of compounds selected

from compounds shown in these sub-groups (III-ci) to (III-cv), the content of the compounds as the liquid crystal component M being within a range from 10 to 100% by weight.

[0187]

Although the liquid crystal component C of the present invention can contain at least one compound selected from one, two, or three or more sub-groups among these sub-groups (III-ai) to (III-cv), the effect can be obtained by composing of only one compound from one sub-group. Compounds capable of having two or more structural features of compounds shown in the sub-groups (III-ai) to (III-cv) are more preferred. The liquid crystal component C can be composed of compounds shown in the above sub-groups (III-ai) to (III-cv) according to the desired purposes.

[0188]

The present invention includes a liquid crystal composition containing a combination of the liquid crystal component A and liquid crystal component C. The present inventors have found that the liquid crystal composition of the present invention has a noticeable effect in response characteristics compared to a liquid crystal composition comprising conventionally known liquid crystal component A and liquid crystal component C. In a liquid crystal composition using in combination with the liquid crystal component C, particularly liquid crystal component C containing sub-groups (III-bi) to (III-cv), and more particularly liquid crystal component C containing sub-groups (III-ci) to (III-cv), a fast



improvement in response characteristics was obtained compared to the liquid crystal composition comprising the liquid crystal component B and liquid crystal component C. It is considered that this is caused by a compound characterized by a molecular structure having, as a partial structure, non-substituted or substituted decahydronaphthalene-2,6-diyl, and particularly a plate-like structure thereof.

[0189]

The liquid crystal component C containing these compounds (III-ai) to (III-cv) has a feature that it can be well mixed with the liquid crystal component A as an essential component, and is particularly useful for preparation according to the purpose of the driving voltage, improvement in temperature dependency and improvement in response characteristics. These compounds are superior in at least one of individual effects and this effect can be obtained even in the case of small content within a range from 0.1 to 30% by weight based on the total amount of the nematic liquid crystal composition of the present invention.

[0190]

The liquid crystal composition of the present invention, which is obtained by using a liquid crystal component C containing, as a principal component, compounds of the general formulas (III-1) to (III-4) related to the liquid crystal composition of the present invention, or a liquid crystal component C containing compounds of the above-described subgroups (III-ai) to (III-cv), or a liquid crystal component C

capable of having two or more structural features of the same groups (III-ai) to (III-cv) in combination with a liquid crystal component A broadens the operating temperature range of liquid crystal display characteristics due to an improvement in co-solubility and storage at low temperature, thereby making it possible to improve a reduction in driving voltage and a change in temperature and to attain comparatively fast response characteristics for a predetermined driving voltage, thus obtaining more improved electro-optical characteristics of TN-LCDs, STN-LCDs, TFT-LCDs, PDLCs, PN-LCDs or the like using the liquid crystal composition as a constituent material.

[0191]

The compounds related to the present invention are capable of consciously substituting constituent atoms with isotope atoms thereof. In this case, compounds in which hydrogen atoms are substituted with deuterium atoms are particularly preferred and exhibit preferable effect due to co-solubility, elastic constant, pre-tilt angle and voltage holding ratio. Preferred mode includes compounds in which hydrogen atoms, which are present in the above linking groups or rings, are substituted with deuterium atoms. More preferably, the side chain group is a substituted or non-substituted alkyl or alkenyl group; the ring is substituted or non-substituted 1,4-phenylene, pyrimidine-2,5-diyl, trans-1,4-cyclohexene, trans-1,4-cyclohexenylene, or trans-1,4-dioxane-2,5-diyl; and the linking group

is  $-\text{CH}_2\text{O}-$ ,  $-\text{OCH}_2-$ ,  $-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_4-$ ,  $-\text{CH}=\text{CH}-(\text{CH}_2)_2-$ ,  $-(\text{CH}_2)_2-\text{CH}=\text{CH}-$ ,  $-\text{CH}=\text{N}-$ , or  $-\text{CH}=\text{N}-\text{N}=\text{CH}-$ . Particularly preferred are alkyl group, alkenyl group, 1,4-phenylene, trans-1,4-cyclohexene,  $-(\text{CH}_2)_2-$  and  $-(\text{CH}_2)_4-$ .

[0192]

The alignment film used in TN-LCDs, STN-LCDs or TFT-LCDs is exclusively a polyimide film and examples thereof include LX1400, SE150, SE610, AL1051, AL3408 and the like. Liquid crystal display characteristics, display quality, reliability and productivity have a close relation with the specification of the alignment film and, for example, pre-tilt angle characteristics are important to the liquid crystal material. The pre-tilt angle must be appropriately adjusted to obtain desired liquid crystal display characteristics and uniform alignment properties. In the case of a large pre-tilt angle, unstable oriented state is liable to occur. In the case of a small pre-tilt angle, it becomes impossible to satisfy sufficient display characteristics.

[0193]

The present inventors have found that liquid crystal materials are classified into a liquid crystal material having a larger pre-tilt angle and a liquid crystal material having a smaller pre-tilt angle, and also found that the desired liquid crystal display characteristics and uniform alignment properties are attained by applying this classifying technique. This technique can also be applied to the present invention. If the liquid crystal component B contains

compounds of the general formulas (II-1) to (II-4), the pre-tilt angle is controlled in the following manner. Larger pre-tilt angle can be obtained by increasing the content of compounds in which  $R^1$  is an alkenyl group,  $X^1$  is F, Cl, or -CN, and  $Y^3$  and  $Y^4$  represent F in the general formula (II-1) and/or compounds in which  $R^1$  is an alkyl group,  $X^1$  is F, Cl, or -CN, and  $Z^5$  is  $-C_2H_4-$  or  $-C_4H_8-$  in the general formula (II-1), while smaller pre-tilt angle can be obtained by increasing the content of compounds in which  $R^1$  is an alkenyl group or  $C_sH_{2s+1}-O-C_tH_{2t}$ ,  $X^1$  is F,  $Y^3$  is F, and  $Y^4$  is H in the general formula (II-1) and/or compounds in which  $Z^5$  is  $-COO-$ .

Specifically, in the case of compounds in which a decahydronaphthalene-2,6-diyl group in the general formulas (I-1) to (I-4) or rings  $A^1$  and  $A^2$  in the general formulas (I-2) to (I-4) are cyclohexane rings, or rings  $A^3$  to  $A^5$  in the general formulas (II-1), (II-2) and (II-4) are cyclohexane rings, or rings  $A^3$ ,  $A^6$  and  $A^7$  in the general formulas (III-1) to (III-4) are cyclohexane ring, and hydrogen atoms of the rings are substituted with deuterium atoms, it makes possible to adjust the pre-tilt angle within a wide range, though it varies depending on the substitution position.

[0194]

Use of a large amount of compounds in which hydrogen atoms are substituted with deuterium atoms exerts a noticeable effect of maintaining higher voltage holding ratio, and is suited for display characteristics and production yield of active TFT-LCDs, PDLCs, PN-LCDs or the like. It is considered

that such an effect is obtained by providing the liquid crystal compound with properties of heavy water, for example, difference in equilibrium constant and velocity constant of the reaction, low ionic mobility, low solubility of inorganic matter and oxygen and the like. Higher voltage holding ratio can be nearly obtained by incorporating the above-described compounds in the amount within a range from 10 to 40% by weight based on the total amount of the liquid crystal composition.

[0195]

Generally, the content of each liquid crystal component in the nematic liquid crystal composition of the present invention is as follows. The content of the liquid crystal component A is within a range from 0.1 to 100% by weight, preferably from 0.5 to 90% by weight, and more preferably from 5 to 85% by weight. The content of the liquid crystal component B is within a range from 0 to 99.9% by weight, preferably from 3 to 80% by weight, and more preferably from 5 to 60% by weight. The content of the liquid crystal component C is 85% by weight or less, preferably within a range from 3 to 70% by weight, more preferably from 5 to 70% by weight. When using the compounds represented by the general formula (I-1), the content is preferably 15% by weight or less in terms of single substance. If the content is 15% or more, the compounds are preferably composed of two or more kinds of compounds and the content of compounds represented by the general formulas (I-1a) to (I-13bs) is preferably within a

range from 5 to 100% by weight based on the liquid crystal component A. The content of compounds represented by the general formulas (II-1) to (II-4), and specifically compounds represented by the general formulas (II-1a) to (II-4g) is preferably 30% by weight or less, and more preferably 25% by weight or less, in terms of single substance. If the content is 30% or more, the compounds are preferably composed of two or more kinds of compounds and the content is within a range from 10 to 100% by weight, preferably from 50 to 100% by weight, and more preferably from 75 to 100% by weight, based on the liquid crystal component B. The content of compounds represented by the general formulas (III-1) to (III-4), and specifically compounds represented by the general formulas (III-1a) to (III-4o) is preferably 30% by weight or less, and more preferably 25% by weight or less, in terms of single substance. If the content is 30% or more, the compounds are preferably composed of two or more kinds of compounds and the content is within a range from 10 to 100% by weight, preferably from 50 to 100% by weight, and more preferably from 75 to 100% by weight, based on the liquid crystal component C.

[0196]

The liquid crystal composition of the present invention may contain conventional nematic liquid crystals, smectic liquid crystals and cholesteric crystals recognized as liquid crystal compounds, in addition to compounds represented by the general formulas (I-1) to (III-4), in order to improve characteristics of the liquid crystal composition. For

example, the liquid crystal composition contain one, or two more kinds of core-structure compounds having four six-membered rings, the liquid crystal phase-isotropic liquid phase transition temperature of said compounds being 100°C or higher. However, since characteristics of the nematic liquid crystal composition are deteriorated by using a large amount of these compounds, the amount is limited according to required characteristics of the resulting nematic liquid crystal composition.

[0197]

Preferred compounds are compounds in which  $k^3$  in the general formulas (II-1) and (II-2) is 2, compounds in which  $k^4+k^5$  in the general formula (II-4) is 2, compounds in which  $k^3$  in the general formulas (III-1) to (III-3) is 2, and compounds in which  $k^4+k^5$  in the general formula (III-4) is 2. In this case, rings  $A^3$  and  $A^6$ , and linking groups  $Z^4$  and  $Z^5$  may be independently the same or different.

[0198]

Crystal phase or smectic phase-nematic phase transition temperature should be 0°C or lower, preferably -10°C or lower, more preferably -20°C or lower and most preferably -30°C or lower. The nematic phase-isotropic liquid phase transition temperature should be 50°C or higher, preferably 60°C or higher, more preferably 70°C or higher and most preferably within a range from 80°C to 180°C. The dielectric constant anisotropy of the liquid crystal composition according to the present invention may have a value not less than 1, but is

preferably within a range from 2 to 40, while it is preferably within a range from 2 to 8 when high speed response is required and preferably within a range from 7 to 30 when a lower driving voltage is required. Lower or medium birefringent index is preferably within a range from 0.02 to 0.18, and higher birefringent index is preferably within a range from 0.18 to 0.40. Such characteristics of the nematic liquid crystal composition are useful for active matrix, twisted nematic or super twisted nematic liquid crystal display device.

[0199]

Distance  $d$  between the substrates in TN-LCD, STN-LCD and TFT-LCD is preferably from 1 to 12  $\mu\text{m}$ , more preferably from 1 to 10  $\mu\text{m}$  and most preferably from 1.5 to 7  $\mu\text{m}$ . Product of the distance  $d$  and the birefringent index  $\Delta n$  is preferably from 0.2 to 5  $\mu\text{m}$ , more preferably from 0.3 to 1.6  $\mu\text{m}$ , and most preferably about 0.5  $\mu\text{m}$ , from 0.7 to 1.0  $\mu\text{m}$  or about 1.2  $\mu\text{m}$ .

[0200]

In the case of PDLCD or PN-LCD, the product described above is preferably from 1 to 100  $\mu\text{m}$ , more preferably from 3 to 50  $\mu\text{m}$ , and most preferably from 4 to 14  $\mu\text{m}$ .

[0201]

When faster response characteristic for the magnitude of the driving voltage is desired, the liquid crystal composition of the present invention may be constituted as follows. For a medium driving voltage, the dielectric constant anisotropy of the liquid crystal composition according to the present



invention is from 3 to 15, and viscosity at 20°C is preferably within a range from 8 to 20 cp. In this case, viscosity of only the liquid crystal component C is preferably 25 cp or lower, more preferably 15 cp or lower, and most preferably 10 cp or lower. For a particularly low driving voltage, the dielectric constant anisotropy of the liquid crystal composition according to the present invention is preferably within a range from 15 to 30, and more preferably within a range from 18 to 28.

[0202]

The nematic liquid crystal composition described above is useful for the use in TN-LCD, STN-LCD and TFT-LCD that have high-speed response characteristic, useful for a liquid crystal display element that is capable of providing color display by means of the birefringent property of a liquid crystal and a retardation plate without using color filters, and can be used in a liquid crystal display element of transmissive type or reflective type. This liquid crystal display element has substrates that have transparent electrode layer, with at least one thereof being transparent, wherein molecules of the nematic liquid crystal composition are disposed in a twisted orientation between the substrates. The twist angle may be selected within a range from 30 to 360° in accordance to the purpose, preferably selected within a range from 90 to 270°, and most preferably selected within a range from 45 to 135° or from 180 to 260°. For this purpose, the liquid crystal composition of the present invention may

include a compound that has an optically active group which causes the induced helical pitch  $p$  to fall within a range from 0.5 to 1000  $\mu\text{m}$ . Such compounds include cholesteric derivative, chiral nematic and ferroelectric liquid crystals. More specifically, compounds in which  $R^1$  in general formulas (I-1) to (I-4),  $R^1$  in general formulas (II-1) to (II-4), and  $R^2$  and  $R^3$  in general formulas (III-1) to (III-4) have optically active groups are preferably used, and specific examples thereof include  $-\text{COOCH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ ,  $-\text{OCH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$ ,  $-\text{COOCH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_3$ ,  $-\text{COOCH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$ ,  $-\text{OCH}(\text{CH}_3)\text{CH}_2\text{CH}_2\text{CH}_3$ ,  $-\text{OCH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$ ,  $-\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$ , and  $-\text{CH}_2\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$ . Typically, cholesteryl nonanate, C-15, CB-15 and S-811 are preferably used. While materials of which induced helical pitch increases and those of which induced helical pitch decreases as the temperature rises are known, one, or two or more kinds of materials of either of these kinds may be used, or one, or two or more kinds of materials of each of these kinds may be used in combination. The amount is preferably within a range from 0.001 to 10% by weight, more preferably within a range from 0.05 to 3% by weight and most preferably within a range from 0.1 to 3% by weight. It needs not to say that the amount is determined to obtain a predetermined induced helical pitch with the twist angle  $\theta$  and the distance  $d$  between the substrates. In the TN-LCD, STN-LCD and TFT-LCD, for example, ratio  $d/p$  of the distance  $d$  between the substrates to the induced helical pitch  $p$  can be set within a range from 0.001

to 24, while the ratio is preferably within a range from 0.01 to 12, more preferably within a range from 0.1 to 2, even more preferably within a range from 0.1 to 1.5, further more preferably within a range from 0.1 to 1, and most more preferably within a range from 0.1 to 0.8.

[0203]

Pre-tilt angle obtained from an oriented film that is provided on the transparent electrode substrate is preferably from  $1^{\circ}$  to  $20^{\circ}$ . When the twist angle is within a range from  $30^{\circ}$  to  $100^{\circ}$ , the pre-tilt angle is preferably from  $1^{\circ}$  to  $4^{\circ}$ . When the twist angle is within a range from  $100^{\circ}$  to  $180^{\circ}$ , the pre-tilt angle is preferably from  $2^{\circ}$  to  $6^{\circ}$ . When the twist angle is within a range from  $180^{\circ}$  to  $260^{\circ}$ , the pre-tilt angle is preferably from  $3^{\circ}$  to  $12^{\circ}$ . When the twist angle is within a range from  $260^{\circ}$  to  $360^{\circ}$ , the pre-tilt angle is preferably from  $6^{\circ}$  to  $20^{\circ}$ .

[0204]

The present inventors have found out that favorable display characteristics can be achieved also with a light scattering type liquid crystal display wherein the liquid crystal composition has a light modulation layer held between two transparent substrates, with at least one of which being transparent, having transparent electrode layers, and the light modulation layer includes a liquid crystal material and a transparent solid substance. The present inventors showed, on Japanese Unexamined Patent Application, First Publication No. Hei 6-222320, that the physical properties of a liquid

crystal material and the display characteristics of the liquid crystal can be related by the following equation (VI).

[0205]

[Equation 1]

$$V_{th} \propto \frac{d}{\langle r \rangle + {}^1K_{ii}/A} \left( \frac{{}^2K_{ii}}{\Delta \epsilon} \right)^{1/2} \quad \text{---(VI)}$$

[0206]

where  $V_{th}$  is the threshold voltage,  ${}^1K_{ii}$  and  ${}^2K_{ii}$  are elastic constants with  $ii$  being 11, 22 or 33,  $\Delta \epsilon$  is the dielectric constant anisotropy,  $\langle r \rangle$  is the mean void distance in the interface of the transparent solid substance,  $A$  is the anchoring energy of the transparent solid substance and  $d$  is the distance between the substrates having the transparent electrodes.

[0207]

This equation means that the restricting force of the interface of the transparent solid substance exerted on the liquid crystal molecules varies according to the ratio of the elastic constant  ${}^1K_{ii}$  and the anchoring energy  $A$ , and particularly shows that the effect thereof is to effectively expand the distance by the amount of  ${}^1K_{ii}/A$  over the actual mean void distance  $\langle r \rangle$ , namely to effectively decrease the driving voltage. This relation can also be utilized in the present invention. Specifically, when the transparent solid substance is formed from a polymerizable compound that

includes difunctional monomer and monofunctional monomer which serve as polymer-forming compounds, the transparent solid substance takes a more uniform structure thereby making it possible to manipulate the property of the interface with the liquid crystal material, in the process of forming the transparent solid substance from the polymer-forming compounds. In the liquid crystal composition according to the present invention, one or plural characteristics among clouding characteristics, response characteristics, hysteresis, sharpness and driving voltage, or the temperature dependency of these characteristics can be improved by the liquid crystal component A that consists of a compound characterized by such a molecular structure having non-substituted or substituted decahydronaphthalene-2,6-diyl group as a partial structure thereof.

[0208]

The liquid crystal material used in the present invention is expected to be useful also for a display apparatus wherein a transparent solid substance interposed between the two substrates that have transparent electrode layers includes liquid crystal droplets, which comprise a liquid crystal material and is contained in microcapsules, being scattered therein. The transparent solid substance interposed between the two substrates may be fibers or particles scattered or a film containing droplets of the liquid material dispersed therein, but more preferably has a three-dimensional network structure. While it is preferable that the liquid crystal

material forms a continuous layer, it is important to form random state of the liquid crystal material in order to form an optical interface and achieve scattering of light. When the average size of the three-dimensional network structure formed from the transparent solid substance is too greater or smaller than the wavelength of light, scattering of light tends to be weaker. Thus the average size is preferably from 0.2 to 2  $\mu\text{m}$ . Thickness of the light modulation layer is preferably from 2 to 30  $\mu\text{m}$ , and more preferably from 5 to 20  $\mu\text{m}$  depending on the application.

[0209]

The light scattering type liquid crystal display of the present invention that is made as described above achieves less temperature-dependent drive characteristics and thereby satisfies the requirements for the active matrix display. The liquid crystal display of the present invention can also be used, for example, in a projection display apparatus and personal digital assistance of direct view type.

[0210]

The liquid crystal composition of the present invention can be obtained by incorporating the liquid crystal components A, B and C described in detail above. Preferred examples are nematic liquid crystals (1-01) to (1-24) described below, but the present invention is not limited by these examples. Among these, for example, nematic liquid crystal compositions (1-01), (1-03) to (1-07), (1-20), (1-21), (1-22) and (1-24) can be used for TN-LCD, nematic liquid crystal compositions (1-


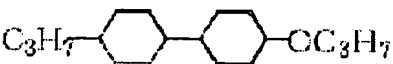
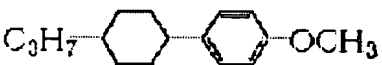

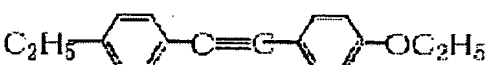
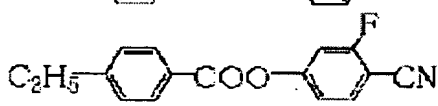
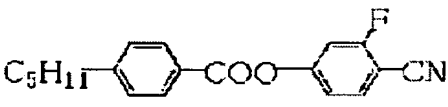
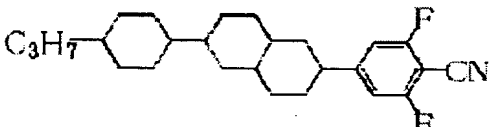

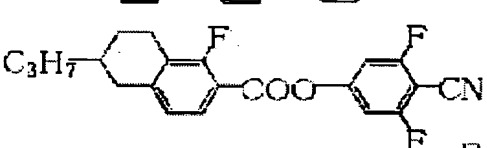
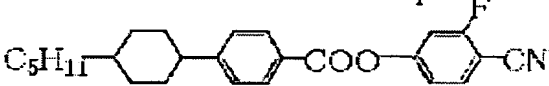
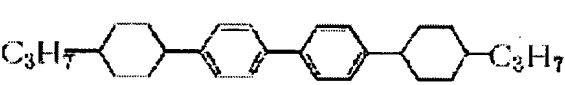
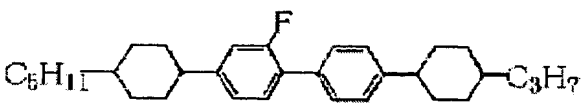
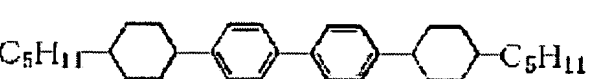
01), (1-02), (1-08), (1-10) to (1-15), (1-17), (1-18), (1-22) and (1-24) can be used for STN-LCD, nematic liquid crystal compositions (1-06), (1-09), (1-16) and (1-20) to (1-23) can be used for TFT-LCD, and nematic liquid crystal compositions (1-09), (1-10), (1-23) and (1-24) can be used for PDLC and PN-LCD. One or plural kinds of these compounds (1-0101) to (1-2411) can be used in place of compounds represented by the general formulas (I-1) to (III-4), more specifically compounds having the basic structures of the general formulas (I-1a) to (I-4ap) in which the side chain groups are (I-5a) to (I-5bc) and the partial structures of the polar group are represented by the general formulas (I-6a) to (I-6r), compounds having the basic structures of the general formulas (II-1a) to (II-4g) in which the side chain groups are (I-5a) to (I-5r) and the partial structures of the polar group are represented by the general formulas (II-6a) to (II-6r), and compounds having the basic structures of the general formulas (III-1a) to (III-4o) in which the side chain groups are (III-5a) to (III-5bf), according to the desired purposes and applications.

[0211]

Examples of preferred composition: nematic liquid crystal composition (1-01)

[0212]

[Chemical Formula 61]

(1-0101)		10 wt%
(1-0102)		10 wt%
(1-0103)		5 wt%
(1-0104)		5 wt%
(1-0105)		5 wt%
(1-0106)		5 wt%
(1-0107)		12 wt%
(1-0108)		10 wt%
(1-0109)		8 wt%
(1-0110)		10 wt%
(1-0111)		5 wt%
(1-0112)		5 wt%
(1-0113)		5 wt%
(1-0114)		5 wt%

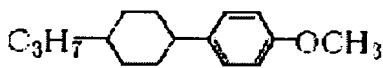
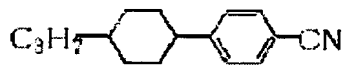
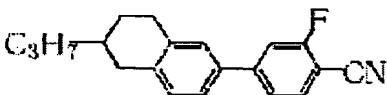

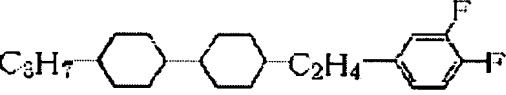
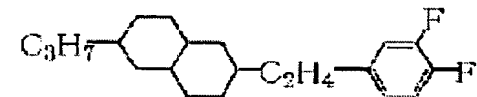
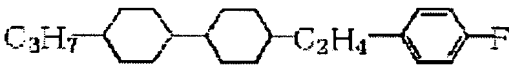
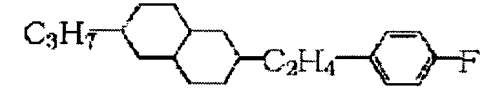
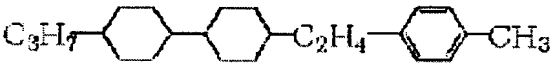
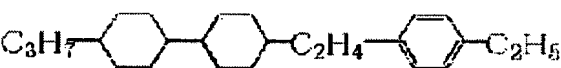
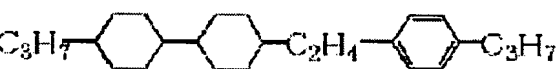


[0213]

Examples of preferred composition: nematic liquid crystal composition (1-02)

[0214]

[Chemical Formula 62]

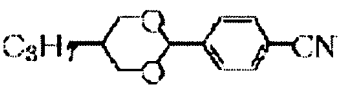
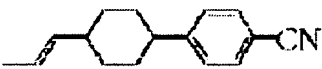
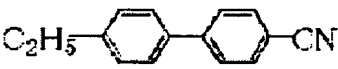
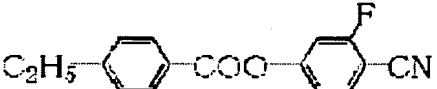
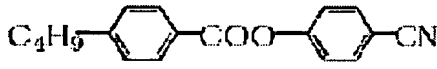
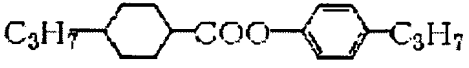
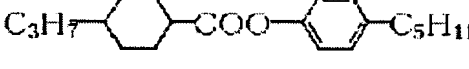
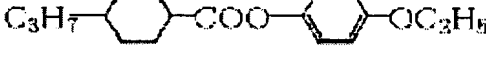
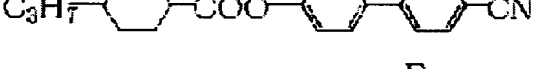

(1-0201)		10 wt%
(1-0202)		8 wt%
(1-0203)		15 wt%
(1-0204)		9 wt%
(1-0205)		6 wt%
(1-0206)		6 wt%
(1-0207)		12 wt%
(1-0208)		12 wt%
(1-0209)		7 wt%
(1-0210)		7 wt%
(1-0211)		8 wt%

[0215]

Examples of preferred composition: nematic liquid crystal composition (1-03)

[0216]

[Chemical Formula 63]

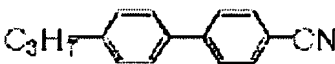


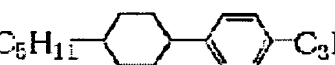
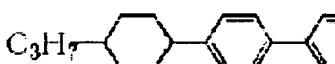
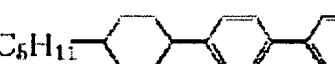

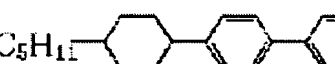


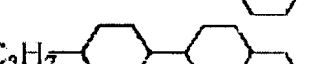



(1-0301)		5 wt %
(1-0302)		5 wt %
(1-0303)		12 wt %
(1-0304)		8 wt %
(1-0305)		9 wt %
(1-0306)		12 wt %
(1-0307)		15 wt %
(1-0308)		13 wt %
(1-0309)		18 wt %
(1-0310)		3 wt %

[0217]

Examples of preferred composition: nematic liquid crystal composition (1-04)

[0218]

[Chemical Formula 64]

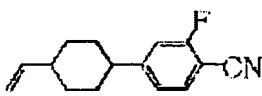
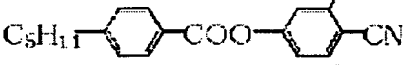
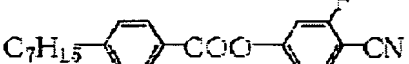
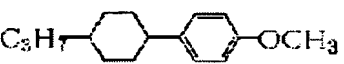


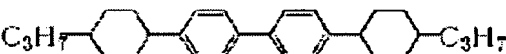

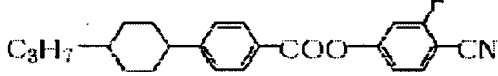
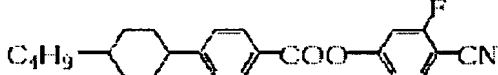

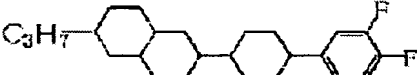
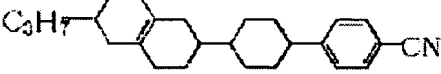
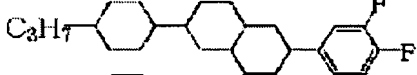

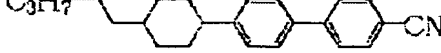
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(1-0405)		10 wt %
(1-0406)		10 wt %
(1-0407)		6 wt %
(1-0408)		5 wt %
(1-0409)		6 wt %
(1-0410)		1 wt %
(1-0411)		1 wt %
(1-0412)		1 wt %
(1-0413)		1 wt %
(1-0414)		1 wt %

[0219]

Examples of preferred composition: nematic liquid crystal composition (1-05)

[0220]

[Chemical Formula 65]

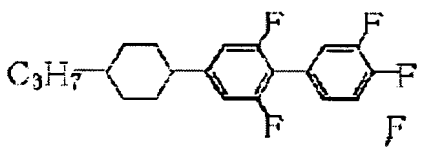
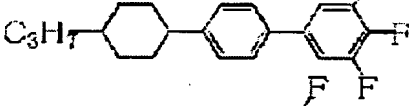

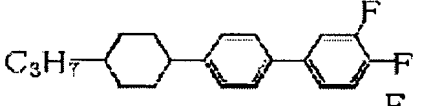
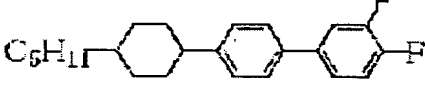
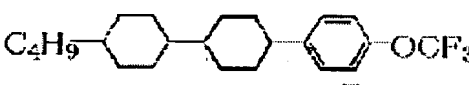
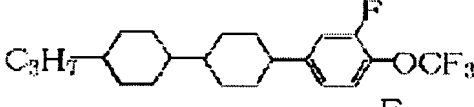
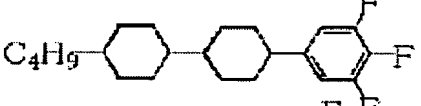
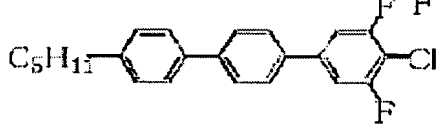
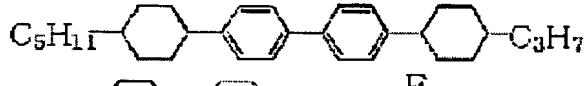
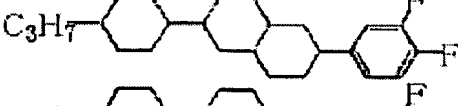

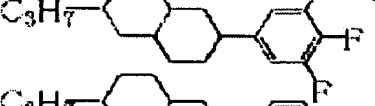

(1-0501)		8 wt%
(1-0502)		10 wt%
(1-0503)		7 wt%
(1-0504)		12 wt%
(1-0505)		18 wt%
(1-0506)		10 wt%
(1-0507)		5 wt%
(1-0508)		5 wt%
(1-0509)		5 wt%
(1-0510)		5 wt%
(1-0511)		5 wt%
(1-0512)		2 wt%
(1-0513)		2 wt%
(1-0514)		2 wt%
(1-0515)		2 wt%
(1-0516)		2 wt%

[0221]

Examples of preferred composition: nematic liquid crystal composition (1-06)

[0222]

[Chemical Formula 66]

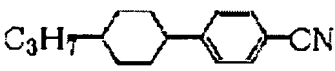
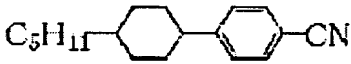
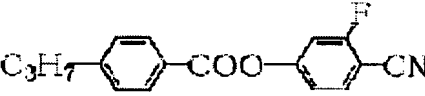
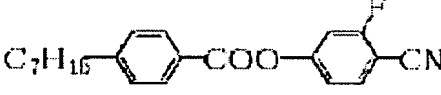
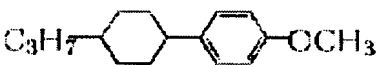
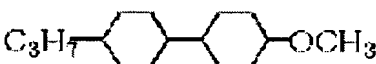
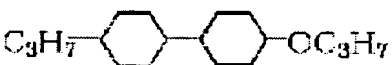


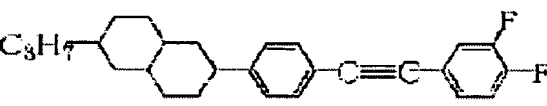

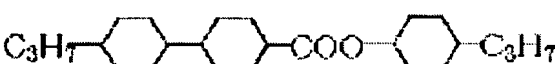
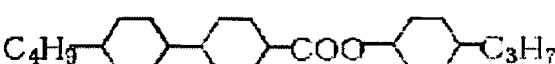
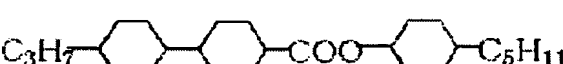
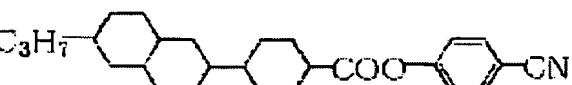
(1-0601)		5 wt%
(1-0602)		5 wt%
(1-0603)		5 wt%
(1-0604)		5 wt%
(1-0605)		10 wt%
(1-0606)		5 wt%
(1-0607)		10 wt%
(1-0608)		10 wt%
(1-0609)		15 wt%
(1-0610)		5 wt%
(1-0611)		5 wt%
(1-0612)		5 wt%
(1-0613)		10 wt%
(1-0614)		5 wt%

[0223]

Examples of preferred composition: nematic liquid crystal composition (1-07)

[0224]

[Chemical Formula 67]

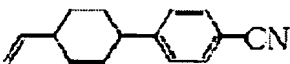
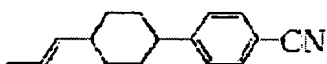
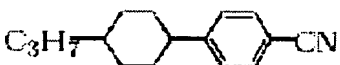
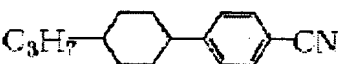
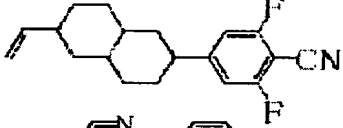
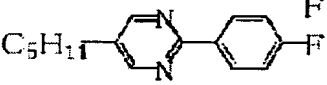

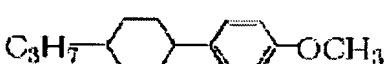

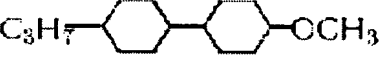
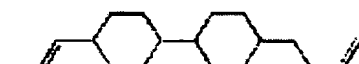
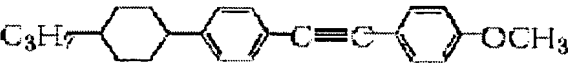
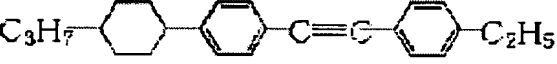

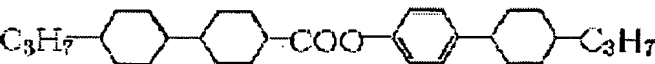
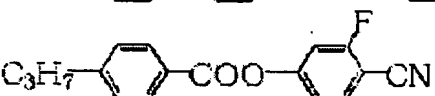
(1-0701)		8 wt %
(1-0702)		6 wt %
(1-0703)		7 wt %
(1-0704)		10 wt %
(1-7705)		11 wt %
(1-0706)		10 wt %
(1-0707)		10 wt %
(1-0708)		10 wt %
(1-0709)		9 wt %
(1-0710)		3 wt %
(1-0711)		3 wt %
(1-0712)		4 wt %
(1-0713)		3 wt %
(1-0714)		3 wt %
(1-0715)		31 wt %

[0225]

Examples of preferred composition: nematic liquid crystal composition (1-08)

[0226]

[Chemical Formula 68]

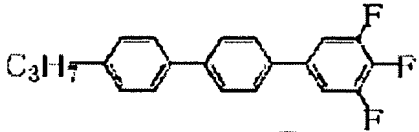
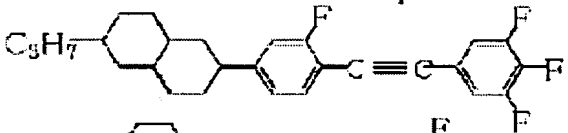
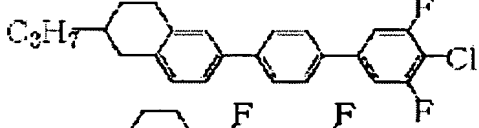
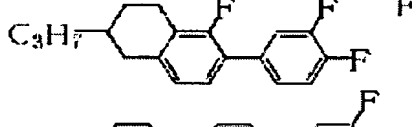
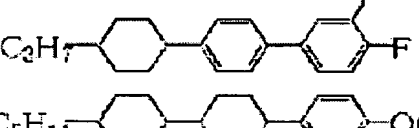
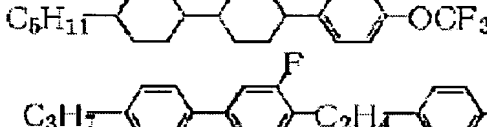
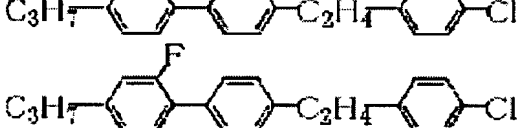

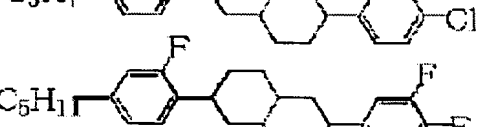
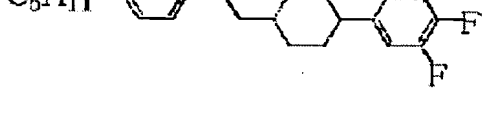
(1-0801)		5 wt %
(1-0802)		10 wt %
(1-0803)		10 wt %
(1-0804)		10 wt %
(1-0805)		10 wt %
(1-0806)		5 wt %
(1-0807)		5 wt %
(1-0808)		3 wt %
(1-0809)		3 wt %
(1-0810)		3 wt %
(1-0811)		3 wt %
(1-0812)		7 wt %
(1-0813)		7 wt %
(1-0814)		7 wt %
(1-0815)		7 wt %
(1-0816)		5 wt %

[0227]

Examples of preferred composition: nematic liquid crystal composition (1-09)

[0228]

[Chemical Formula 69]

(1-0901)		8 wt%
(1-0902)		12 wt%
(1-0903)		11 wt%
(1-0904)		9 wt%
(1-0905)		9 wt%
(1-0906)		9 wt%
(1-0907)		11 wt%
(1-0908)		11 wt%
(1-0909)		10 wt%
(1-0910)		10 wt%

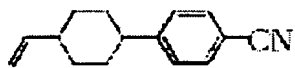
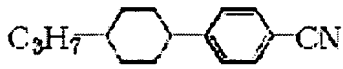
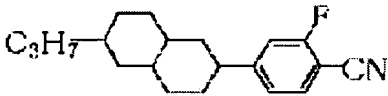
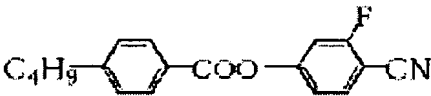
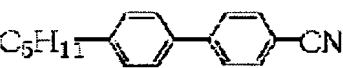
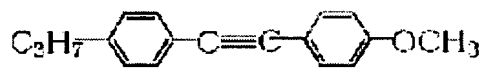
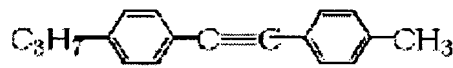
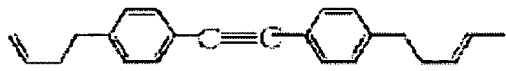
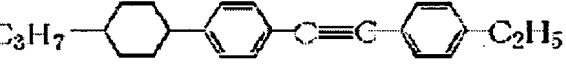
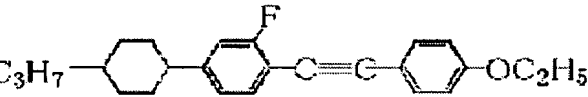
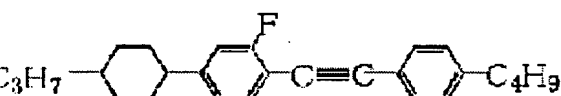





[0229]

Examples of preferred composition: nematic liquid crystal composition (1-10)

[0230]

[Chemical Formula 70]

(1-1001)		10 wt%
(1-1002)		16 wt%
(1-1003)		10 wt%
(1-1004)		4 wt%
(1-1005)		8 wt%
(1-1006)		5 wt%
(1-1007)		3 wt%
(1-1008)		5 wt%
(1-1009)		8 wt%
(1-1010)		8 wt%
(1-1011)		8 wt%
(1-1012)		5 wt%
(1-1013)		5 wt%
(1-1014)		5 wt%

[0231]

Examples of preferred composition: nematic liquid crystal composition (1-11)

[0232]

[Chemical Formula 71]

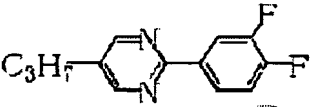
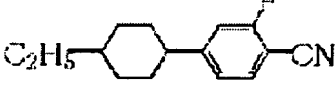
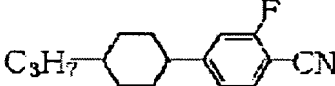
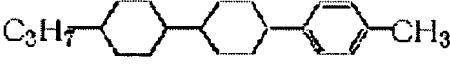
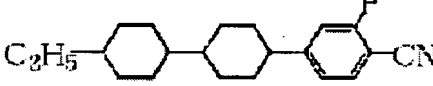
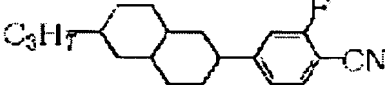

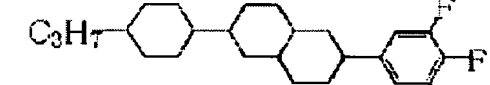
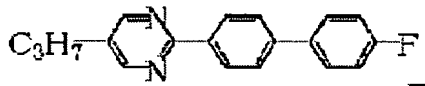
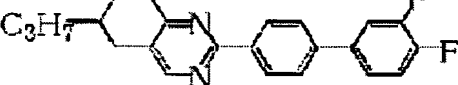

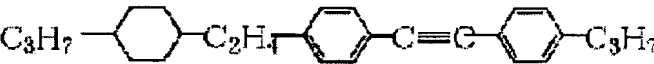
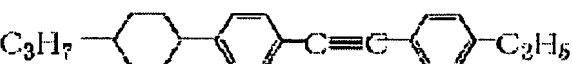
(1-1101)		12 wt%
(1-1102)		11 wt%
(1-1103)		14 wt%
(1-1104)		11 wt%
(1-1105)		6 wt%
(1-1106)		5 wt%
(1-1107)		5 wt%
(1-1108)		5 wt%
(1-1109)		5 wt%
(1-1110)		5 wt%
(1-1111)		5 wt%
(1-1112)		5 wt%
(1-1113)		5 wt%
(1-1114)		6 wt%

[0233]

Examples of preferred composition: nematic liquid crystal composition (1-12)

[0234]

[Chemical Formula 72]


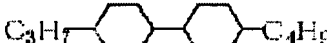
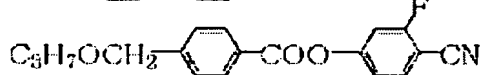
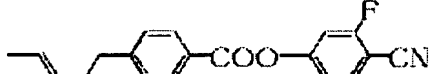
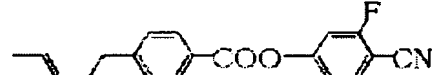
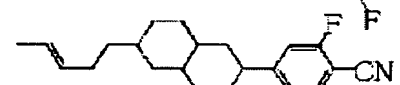
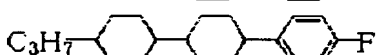
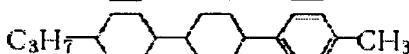

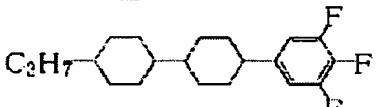
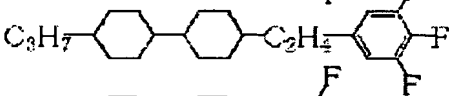
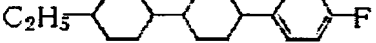
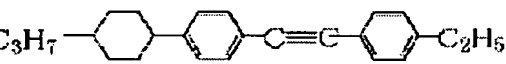
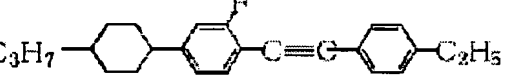


(1-1201)		13. wt %
(1-1202)		16. wt %
(1-1203)		4 wt %
(1-1204)		7. wt %
(1-1205)		12. wt %
(1-1206)		12. wt %
(1-1207)		5. wt %
(1-1208)		5. wt %
(1-1209)		7. wt %
(1-1210)		7. wt %
(1-1211)		4. wt %
(1-1212)		4. wt %
(1-1213)		4. wt %

[0235]

Examples of preferred composition: nematic liquid crystal composition (1-13)

[0236]

[Chemical Formula 73]



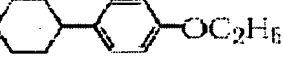
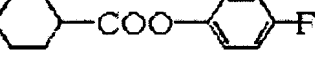
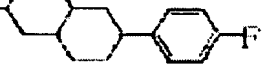

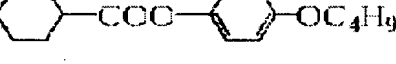


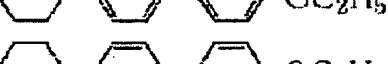





(1-1301)		9 wt%
(1-1302)		4 wt%
(1-1303)		4 wt%
(1-1304)		5 wt%
(1-1305)		4 wt%
(1-1306)		4 wt%
(1-1307)		5 wt%
(1-1308)		21 wt%
(1-1309)		2 wt%
(1-1310)		6 wt%
(1-1311)		5 wt%
(1-1312)		5 wt%
(1-1313)		5 wt%
(1-1314)		6 wt%
(1-1315)		8 wt%
(1-1316)		7 wt%

[0237]

Examples of preferred composition: nematic liquid crystal composition (1-14)

[0238]

[Chemical Formula 74]

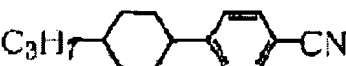
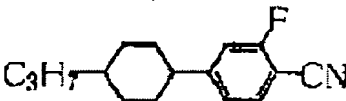



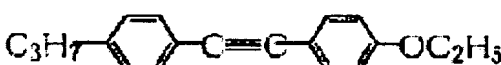





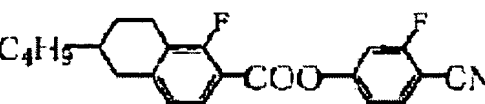
(1-1401)	$C_2H_5$ - 	12 wt %
(1-1402)	$C_3H_7$ - 	12 wt %
(1-1403)	$C_3H_7$ - 	9 wt %
(1-1404)	$C_5H_{11}$ - 	8 wt %
(1-1405)	$C_5H_{11}$ - 	9 wt %
(1-1406)	$C_3H_7$ - 	5 wt %
(1-1407)	$C_3H_7$ - 	5 wt %
(1-1408)	$C_4H_9$ - 	5 wt %
(1-1409)	$C_5H_{11}$ - 	5 wt %
(1-1410)	$C_3H_7$ - 	6 wt %
(1-1411)	$C_3H_7$ - 	5 wt %
(1-1412)	$C_2H_5$ - 	4 wt %
(1-1413)	$C_3H_7$ - 	5 wt %
(1-1414)	$C_2H_5$ - 	5 wt %
(1-1415)	$C_3H_7$ - 	5 wt %

[0239]

Examples of preferred composition: nematic liquid crystal composition (1-15)

[0240]

[Chemical Formula 75]

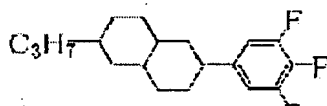
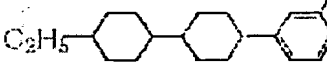
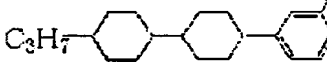
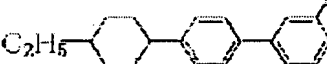
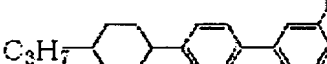




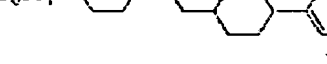
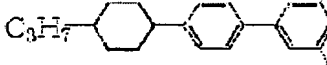


(1-1501)		15 wt %
(1-1502)		10 wt %
(1-1503)		10 wt %
(1-1504)		10 wt %
(1-1505)		7 wt %
(1-1506)		5 wt %
(1-1507)		13 wt %
(1-1508)		14 wt %
(1-1509)		4 wt %
(1-1510)		4 wt %
(1-1511)		5 wt %
(1-1512)		3 wt %

[0241]

Examples of preferred composition: nematic liquid crystal composition (1-16)

[0242]

[Chemical Formula 76]

(1-1601)		10 wt %
(1-1602)		6 wt %
(1-1603)		7 wt %
(1-1604)		4 wt %
(1-1605)		4 wt %
(1-1606)		7 wt %
(1-1607)		9 wt %
(1-1608)		9 wt %
(1-1609)		9 wt %
(1-1610)		10 wt %
(1-1611)		7 wt %
(1-1612)		9 wt %
(1-1613)		9 wt %

[0243]

Examples of preferred composition: nematic liquid crystal composition (1-17)

[0244]

[Chemical Formula 77]

(1-1701)		4 wt%
(1-1702)		3 wt%
(1-1703)		3 wt%
(1-1704)		3 wt%
(1-1705)		3 wt%
(1-1706)		3 wt%
(1-1707)		4 wt%
(1-1708)		18 wt%
(1-1709)		17 wt%
(1-1710)		17 wt%
(1-1711)		4 wt%
(1-1712)		7 wt%
(1-1713)		4 wt%
(1-1714)		5 wt%
(1-1715)		5 wt%


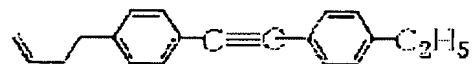
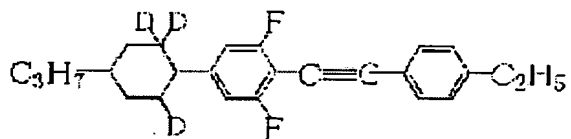
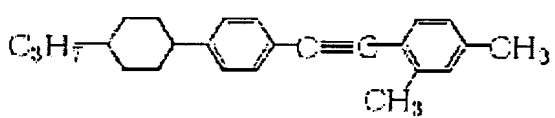
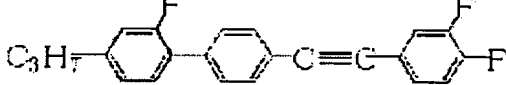
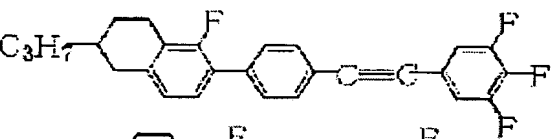
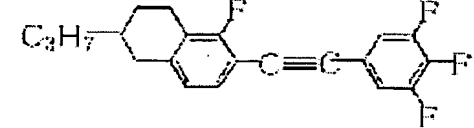
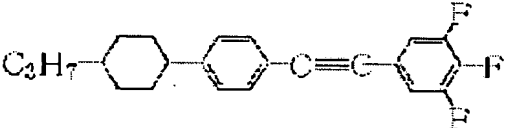


[0245]

Examples of preferred composition: nematic liquid crystal composition (1-18)

[0246]

[Chemical Formula 78]



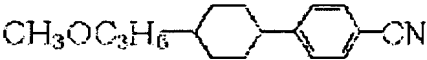
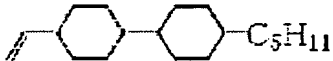








(1-1801)		15 wt%
(1-1802)		15 wt%
(1-1803)		15 wt%
(1-1804)		15 wt%
(1-1805)		15 wt%
(1-1806)		10 wt%
(1-1807)		5 wt%
(1-1808)		10 wt%

[0247]

Examples of preferred composition: nematic liquid crystal composition (1-19)

[0248]

[Chemical Formula 79]

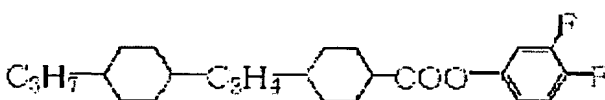
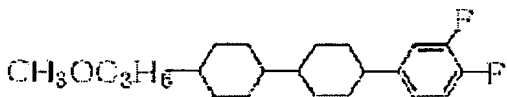
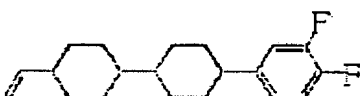
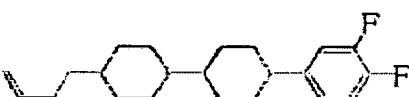
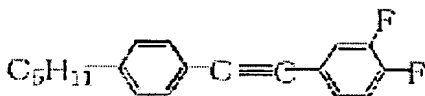
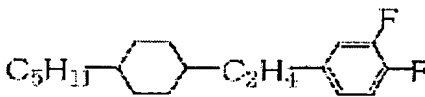
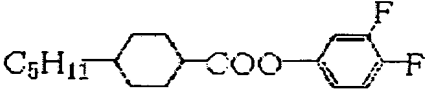
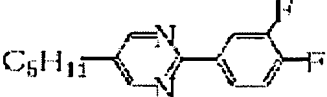


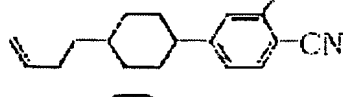
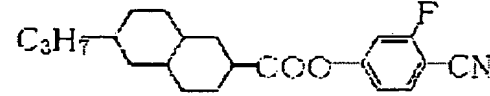
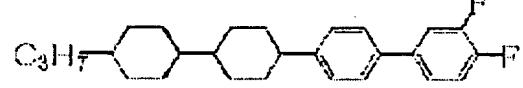
(1-1901)		12 wt %
(1-1902)		10 wt %
(1-1903)		7 wt %
(1-1904)		19 wt %
(1-1905)		4 wt %
(1-1906)		13 wt %
(1-1907)		4 wt %
(1-1908)		7 wt %
(1-1909)		3 wt %
(1-1910)		6 wt %
(1-1911)		3 wt %
(1-1912)		12 wt %

[0249]

Examples of preferred composition: nematic liquid crystal composition (1-20)

[0250]

[Chemical Formula 80]

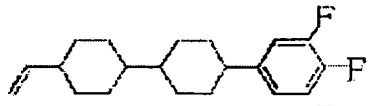
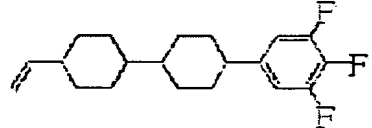
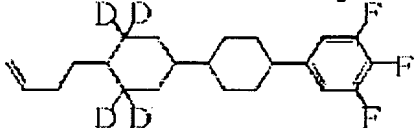
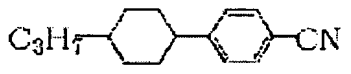
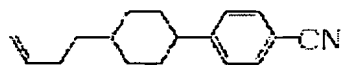
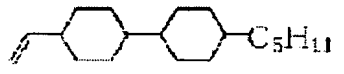
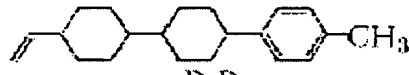
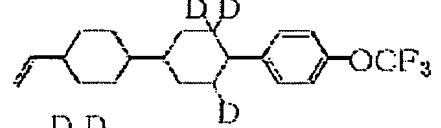
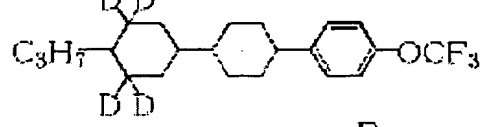
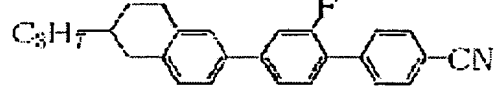
(1-2001)		10 wt %
(1-2002)		7 wt %
(1-2003)		20 wt %
(1-2004)		20 wt %
(1-2005)		5 wt %
(1-2006)		5 wt %
(1-2007)		5 wt %
(1-2008)		5 wt %
(1-2009)		5 wt %
(1-2010)		5 wt %
(1-2011)		5 wt %
(1-2012)		5 wt %
(1-2013)		3 wt %

[0251]

Examples of preferred composition: nematic liquid crystal composition (1-21)

[0252]

[Chemical Formula 81]

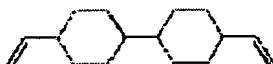
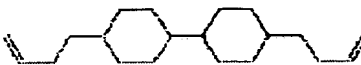
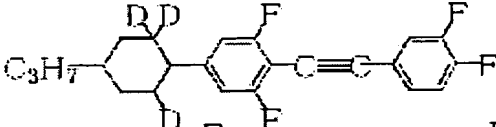
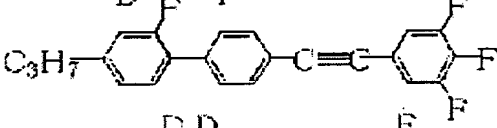
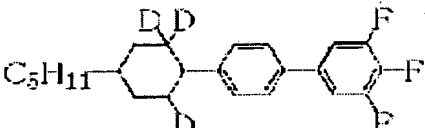
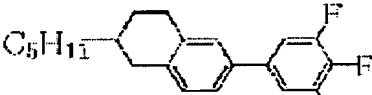
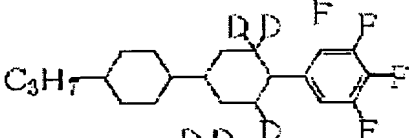
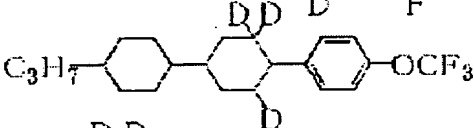
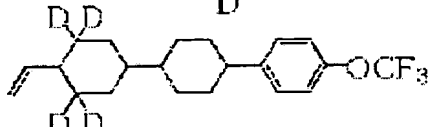
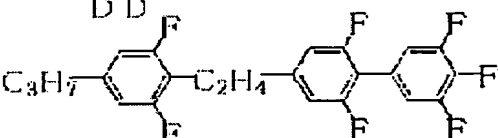
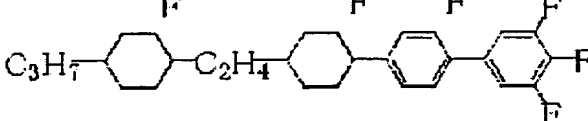
(1-2101)		10 wt %
(1-2102)		10 wt %
(1-2103)		10 wt %
(1-2104)		10 wt %
(1-2105)		10 wt %
(1-2106)		10 wt %
(1-2107)		10 wt %
(1-2108)		10 wt %
(1-2109)		10 wt %
(1-2110)		10 wt %

[0253]

Examples of preferred composition: nematic liquid crystal composition (1-22)

[0254]

[Chemical Formula 82]

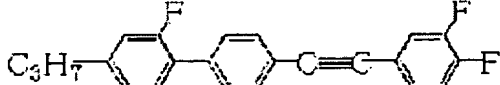
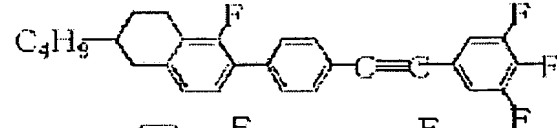
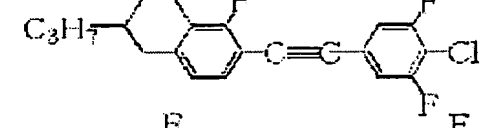
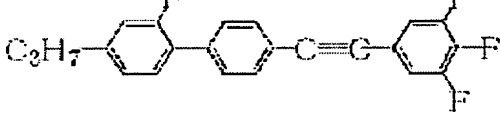
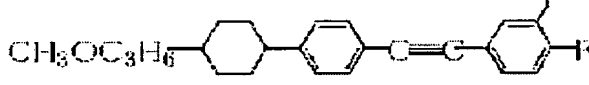
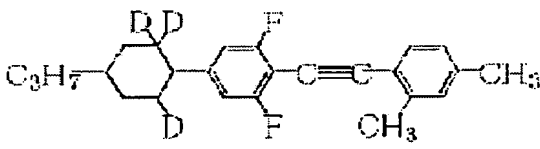
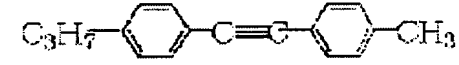
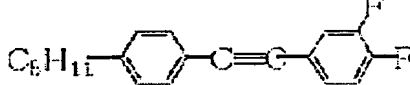
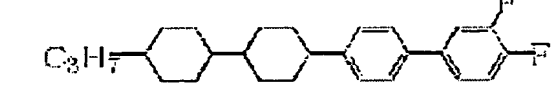
(1-2201)		10 wt%
(1-2202)		10 wt%
(1-2203)		15 wt%
(1-2204)		15 wt%
(1-2205)		10 wt%
(1-2206)		5 wt%
(1-2207)		5 wt%
(1-2208)		10 wt%
(1-2209)		10 wt%
(1-2210)		5 wt%
(1-2211)		5 wt%

[0255]

Examples of preferred composition: nematic liquid crystal  
composition (1-23)

[0256]

[Chemical Formula 83]

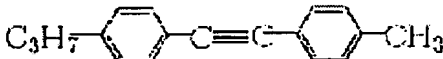
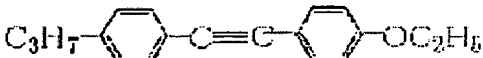
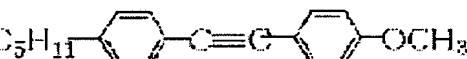

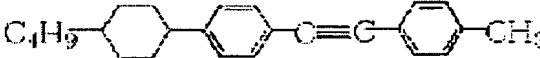
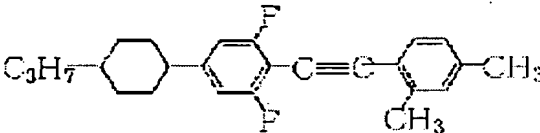

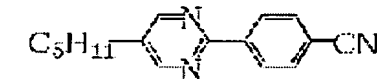
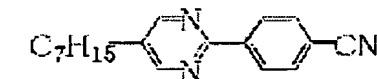

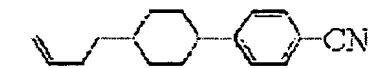
(1-2301)		10 wt%
(1-2302)		10 wt%
(1-2303)		10 wt%
(1-2304)		15 wt%
(1-2305)		15 wt%
(1-2306)		15 wt%
(1-2307)		15 wt%
(1-2308)		7 wt%
(1-2309)		3 wt%

[0257]

Examples of preferred composition: nematic liquid crystal composition (1-24)

[0258]

[Chemical Formula 84]

(1-2401)	$C_3H_7$ - 	20 wt%
(1-2402)	$C_3H_7$ - 	10 wt%
(1-2403)	$C_5H_{11}$ - 	5 wt%
(1-2404)	$C_3H_7$ - 	7 wt%
(1-2405)	$C_4H_9$ - 	8 wt%
(1-2406)	$C_3H_7$ - 	10 wt%
(1-2407)	$C_4H_9$ - 	6 wt%
(1-2408)	$C_5H_{11}$ - 	7 wt%
(1-2409)	$C_7H_{15}$ - 	7 wt%
(1-2410)		10 wt%
(1-2411)		10 wt%

[0259]

The market of the liquid crystal display device is in the state of fierce price competition. To survive this competition, the liquid crystal material is required to be capable of easily optimize the display characteristics for

various applications. Thus such systematized liquid crystal materials 2-bottle type composed of two kinds of liquid crystal material or 4-bottle type composed of four kinds of liquid crystal material. Representative characteristics thereof include the threshold voltage, the birefringent index and the nematic phase-isotropic liquid phase transition temperature. For example, when such a 2-bottle system is used that consists of a liquid crystal material having a higher threshold voltage and a liquid crystal material having a lower threshold voltage, which are identical with regards to other characteristics, requirements can be met more quickly at a lower cost by combining two kinds of liquid crystal materials in a proper proportion without restriction of the electronics components used in the drive circuit. The present invention is useful for this purpose, too, and allows it to use a mixture of the nematic liquid crystal compositions (1-01) to (1-17) and compositions obtained by substituting a part thereof. Such an application may be carried out, as a matter of course, including nematic liquid crystal compositions of Examples to be described later.

[0260]

[EXAMPLES]

The present invention will now be described in detail below by way of Examples, although it should be understood that the present invention is not limited to these Examples. In the following description of compositions of the Examples, "percentages" are by weight unless otherwise specified,



while  $-(\text{CH}_2)_2-$  and  $-\text{C}_2\text{H}_4-$  have the same meaning and  $-(\text{CH}_2)_4-$  and  $-\text{C}_4\text{H}_8-$  have the same meaning.

[0261]

Physical properties of the liquid crystal composition and the display characteristics of the liquid crystal display device that employs the TN-LCD of the Examples are as follows.

$T_{\text{N-I}}$ : Nematic phase-isotropic liquid phase transition temperature ( $^{\circ}\text{C}$ )

$T_{\text{-N}}$ : Solid phase or smectic phase-nematic phase transition temperature ( $^{\circ}\text{C}$ )

$\Delta\epsilon$ : Dielectric constant anisotropy at  $20^{\circ}\text{C}$

$\Delta n$ : Birefringent index at  $20^{\circ}\text{C}$

$\eta$ : Viscosity at  $20^{\circ}\text{C}$  (cp)

$V_{\text{th}}$ : Threshold voltage (V) at  $20^{\circ}\text{C}$  when TN-LCD is constituted

$\gamma$ : Ratio of saturation voltage ( $V_{\text{sat}}$ ) and  $V_{\text{th}}$ , namely sharpness at  $20^{\circ}\text{C}$

$\tau_{\text{r}}=\tau_{\text{d}}$ : Period of time when the rise time  $\tau_{\text{r}}$  if a predetermined voltage is applied starting from 0 V and the decay time  $\tau_{\text{d}}$  if the voltage is decreased from the predetermined voltage to zero equal to each other, at  $20^{\circ}\text{C}$

[0262]

The liquid crystal display device having the STN-LCD display characteristics was made as follows. A chiral material S-811 (manufactured by Merc) was added to the liquid crystal composition, thereby preparing a mixed liquid crystal. An alignment film was formed by rubbing an organic film of Sun-Ever 610 (manufactured by Nissan Chemical Industries,

Ltd.) onto an opposing planar transparent electrode, thereby to make STN-LCD display cell having a twist angle of 240 degrees. The mixed liquid crystal was poured into the cell, thereby to make the liquid crystal display device. The chiral material was added to the liquid crystal composition in such a proportion that the intrinsic helical pitch  $P$  of the mixed liquid crystal and the thickness  $d$  of the display cell satisfy the relations  $\Delta n \cdot d = 0.85$  and  $d/P = 0.50$ . Threshold voltage, sharpness, temperature dependence of the driving voltage and response speed of this mixed liquid crystal were measured.

Display characteristics of the STN-LCD having a twist angle of 240 degrees

$V_{th}$ : Threshold voltage (V) at 20°C

$\gamma$ : Ratio of saturation voltage ( $V_{sat}$ ) and  $V_{th}$ , namely sharpness at 20°C

$\Delta(V_{th})/\Delta(T)$ : Temperature dependence of the driving voltage

$\tau_r = \tau_d$ : Response time when driven with duty ratio of 1/240

[0263]

Chemical stability of the composition was checked by heating acceleration test wherein an ampoule filled with 2 grams of the liquid crystal composition was subjected to substitution with nitrogen after evacuating the inside, before undergoing the test at 150°C for one hour. Resistivity before the heating acceleration test, resistivity after heating acceleration test, voltage holding ratio before heating acceleration test and voltage holding ratio after heating acceleration test of the liquid crystal composition were

measured.

[0264]

One or plural kinds of compounds described in the Examples can be used in place of compounds represented by the general formulas (I-1) to (III-4) according to the desired purposes and applications. Specific compounds are represented by the form of the following examples.

Liquid crystal component A

Examples of the general formula (I-1) compound (2-11): side chain group (I-5a), basic structure (I-1a), and polar group (I-6a)

Examples of the general formula (I-2) compound (2-12): side chain group (I-5a), basic structure (I-2a), and polar group (I-6a)

Examples of the general formula (I-3) compound (2-13): side chain group (I-5a), basic structure (I-3a), and polar group (I-6a)

Examples of the general formula (I-4) compound (2-13): side chain group (I-5a), basic structure (I-4a), and polar group (I-6a)

Liquid crystal component B

Examples of the general formula (II-1) compound (2-21): side chain group (I-5a), basic structure (II-1a), and polar group (II-6a)

Examples of the general formula (II-2) compound (2-22): side chain group (I-6a), basic structure (II-2a), and polar group (II-6a)

Examples of the general formula (II-3) compound (2-23): side chain group (I-5a), basic structure (II-3a), and polar group (II-6a)

Examples of the general formula (II-4) compound (2-24): side chain group (I-5a), basic structure (II-4a), and polar group (II-6a)

Liquid crystal component C

Examples of the general formula (III-1) compound (2-31): side chain group (III-5b), basic structure (III-1a), and side chain group (III-5b)

Examples of the general formula (III-2) compound (2-32): side chain group (III-5b), basic structure (III-2a), and side chain group (III-5b)

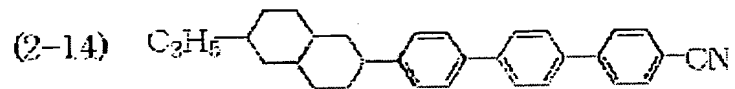
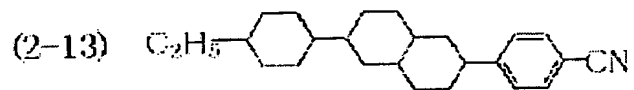
Examples of the general formula (III-3) compound (2-33): side chain group (III-5b), basic structure (III-3a), and side chain group (III-5b)

Examples of the general formula (III-4) compound (2-34): side chain group (III-5b), basic structure (III-4a), and side chain group (III-5b)

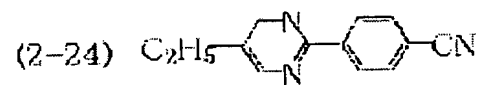
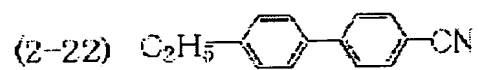
[0265]

[Chemical Formula 85]

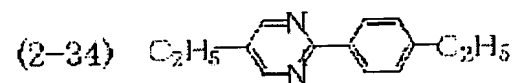
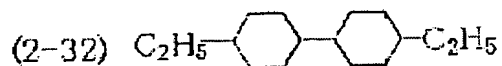
Liquid crystal component A



Liquid crystal component B



Liquid crystal component C

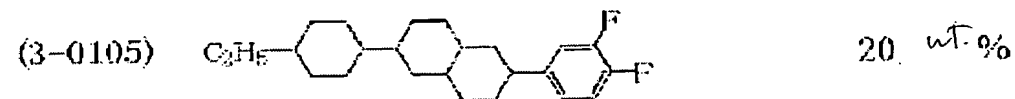
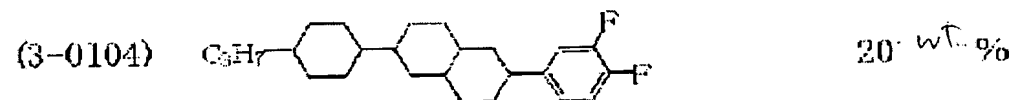
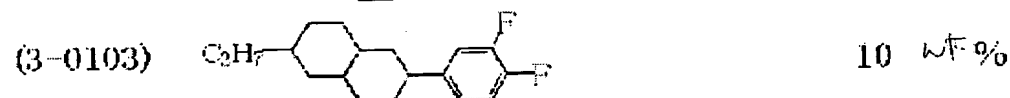
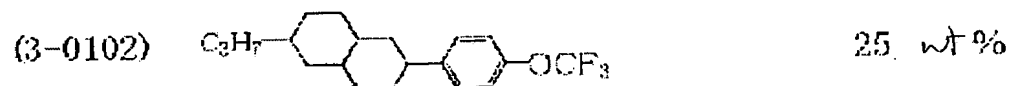


[0266]

(Example 1)

A nematic liquid crystal composition (3-01) was prepared from

[Chemical Formula 86]



and various properties of this composition were measured. The results are as follows.

Physical properties of liquid crystal composition

$T_{N-I}$  : 83.5°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 4.5

$\Delta n$  : 0.073

Reliability characteristics of liquid crystal composition

Resistivity before heating acceleration test:  $1.2 \times 10^{13}$

$\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $7.7 \times 10^{12} \Omega \cdot$

cm.

Voltage holding ratio before heating acceleration test:

99.8%

Voltage holding ratio after heating acceleration test:

98.8%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.79 V

$\gamma$  : 1.284

[0267]

The nematic liquid crystal composition is, despite of being composed of five kinds of components, capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is therefore capable of operating even for high resolution display corresponding to a large duty number. Also because this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it

can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

[0268]

In the same manner as in the case of the nematic liquid crystal composition (3-01), except that the compound (2-01-01) described below was used in place of the compound (3-0103) in the nematic liquid crystal composition (3-01) of this Example, a nematic liquid crystal composition (3-01-01) was prepared. Also in the same manner as in the case of the nematic liquid crystal composition (3-01), except that the respective compounds (2-01-02) to (2-01-012) described below were used in place of the compound (3-0101) in the nematic liquid crystal composition (3-01) of this Example, nematic liquid crystal compositions (3-01-02) to (3-01-12) were prepared. Furthermore in the same manner as in the case of the nematic liquid crystal composition (3-01), except that the respective compounds (2-01-13) to (2-01-025) described below were used in place of the compound (3-0103) in the nematic liquid crystal composition (3-01) of this Example, nematic liquid crystal compositions (3-01-13) to (3-01-25) were prepared.

[0269]

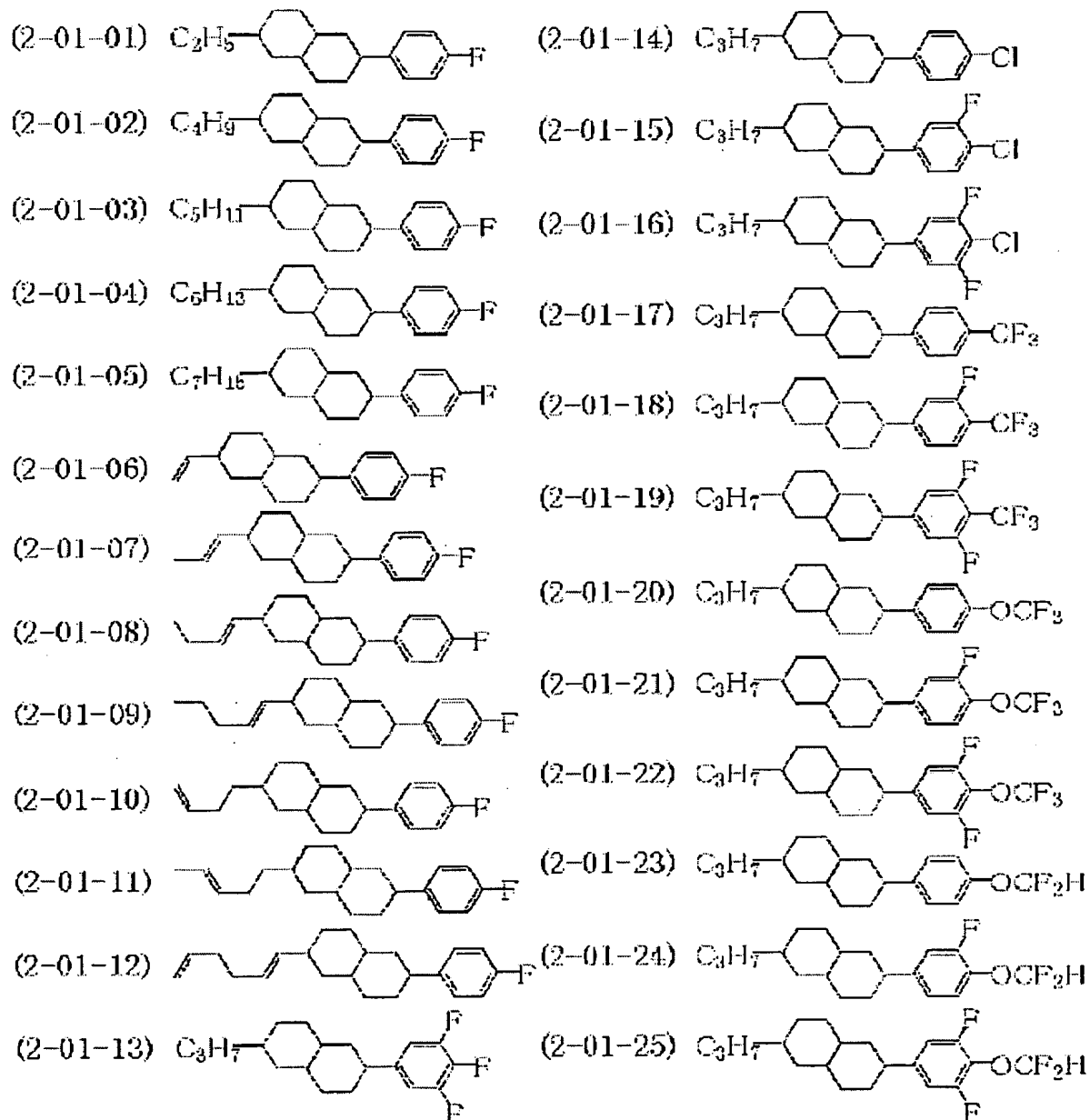
The display characteristics of these nematic liquid crystal compositions (3-01-01) to (3-01-25) showed good results, similar to this Example. Particularly, the nematic



liquid crystal composition (3-01-06) was superior in response characteristics, while the nematic liquid crystal compositions (3-01-01), (3-01-13), (3-01-16), (3-01-19) and (3-01-22) and (3-01-25) exhibited the reduced driving voltage of about 1.5 V.

[0270]

[Chemical Formula 87]



[0271]

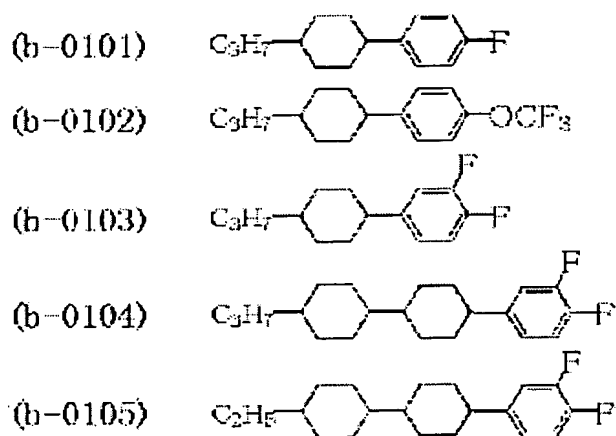
(Comparative Example 1)

In order to demonstrate the superiority of the present invention, a mixed liquid crystal (b-01) made by substituting

the liquid crystal component A of the nematic liquid crystal composition (3-01) described above with another compound. Specifically, the compound was replaced by a compound in which the decahydronaphthalene-2,6-diyl group is substituted with a 1,4-cyclohexylene group. The results are as follows.

[0272]

[Chemical Formula 88]



The mixed liquid crystal (b-01) is composed of the above compounds.

Physical properties of liquid crystal composition

$T_{N-I}$	:	$-4^{\circ}\text{C}$
$\Delta\varepsilon$	:	Impossible to measure
$\Delta n$	:	Impossible to measure
$\eta$	:	Impossible to measure

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ )

$V_{th}$	:	Impossible to measure
$\gamma$	:	Impossible to measure

$\tau_r = \tau_d$  : Impossible to measure

Display characteristics of the STN-LCD having a twist angle of 240 degrees

$V_{th}$  : Impossible to measure

$\gamma$  : Impossible to measure

$\Delta(V_{th})/\Delta(T)$  Impossible to measure

$\tau_r = \tau_d$  : Impossible to measure

[0273]


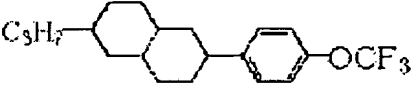



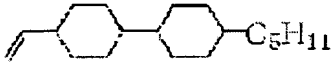

In contrast to the mixed liquid crystal (b-01) which has nematic phase at temperatures of 0°C and lower and therefore cannot be used in an ordinary temperature range, the nematic liquid crystal composition (3-01) of the present invention proved to have high  $T_{N-I}$  and a similar level of  $T_{-N}$ , and is therefore capable of operating over a wide range of temperatures with high co-solubility.

[0274]

(Example 2)

A nematic liquid crystal composition (3-02) was prepared from

## [Chemical Formula 89]

(3-0201)		15 wt %
(3-0202)		15 wt %
(3-0203)		10 wt %
(3-0204)		20 wt %
(3-0205)		15 wt %
(3-0206)		15 wt %
(3-0207)		10 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$	:	80.2°C
$T_{-N}$	:	-70. °C
$\Delta\epsilon$	:	3.9
$\Delta n$	:	0.078

Reliability characteristics of liquid crystal composition

Resistivity before heating acceleration test:  $1.1 \times 10^{13}$

$\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $7.3 \times 10^{12} \Omega \cdot$

cm

Voltage holding ratio before heating acceleration test:

99.0%

Voltage holding ratio after heating acceleration test:

98.8%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.82 V

$\gamma$  : 1.276

[0275]

The nematic liquid crystal composition is, despite of being composed of seven kinds of components, capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_N$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is therefore capable of operating even for high resolution display corresponding to a large duty number. Also because this nematic liquid crystal composition has high resistivity and high voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

[0276]

The following nematic liquid compositions are prepared.

[0277]

In the same manner as in the case of the nematic liquid crystal composition (3-02), except that the respective

compounds (2-02-01) to (2-02-55) described below were used in place of the compound (3-0205) in the nematic liquid crystal composition (3-02) of this Example, nematic liquid crystal compositions (3-02-01) to (3-02-55) were prepared. Also in the same manner as in the case of the nematic liquid crystal composition (3-02), except that the respective compounds (2-02-56) to (2-02-87) described below were used in place of the compound (3-0204) in the nematic liquid crystal composition (3-02) of this Example, nematic liquid crystal compositions (3-02-56) to (3-02-87) were prepared.

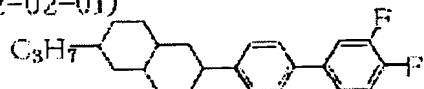
[0278]

The display characteristics of these nematic liquid crystal compositions (3-02-01) to (3-02-87) showed good results, similar to this Example.

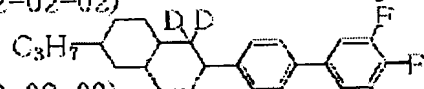
[0279]

[Chemical Formula 90]

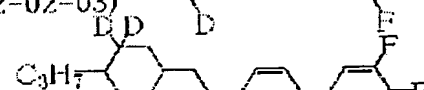
(2-02-01)



(2-02-02)



(2-02-03)



(2-02-04)



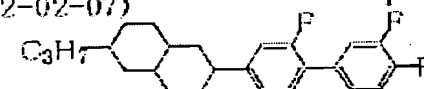
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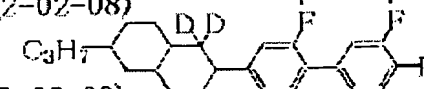
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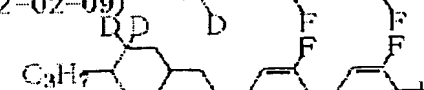
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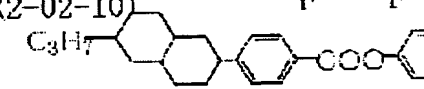
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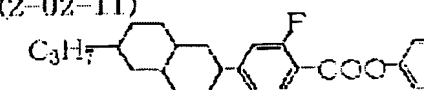
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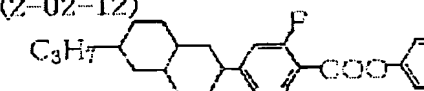
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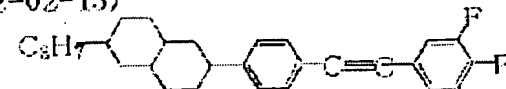
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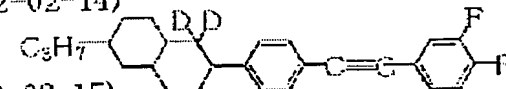
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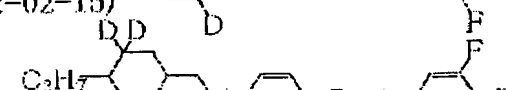
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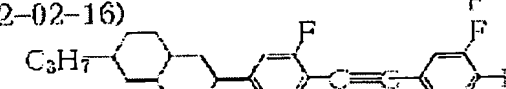
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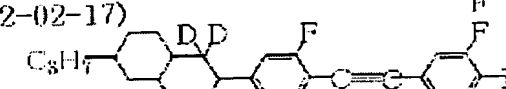
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(2-02-16)



(2-02-17)



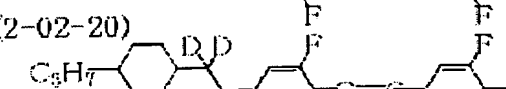
(2-02-18)



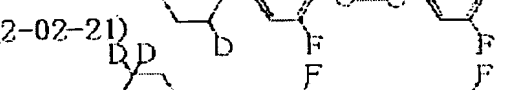
(2-02-19)



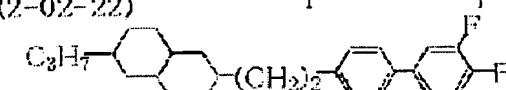
(2-02-20)



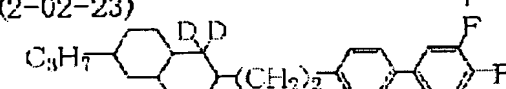
(2-02-21)



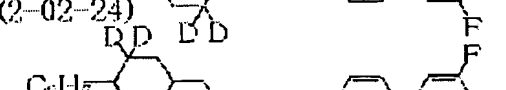
(2-02-22)



(2-02-23)



(2-02-24)

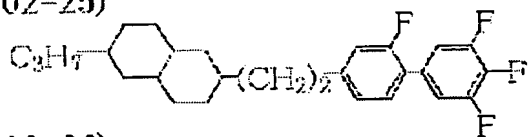




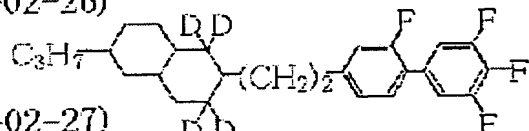
[0280]

[Chemical Formula 91]

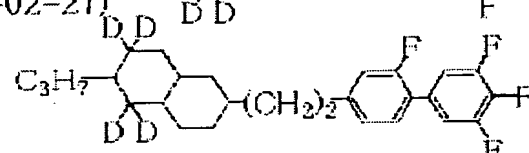
(2-02-25)



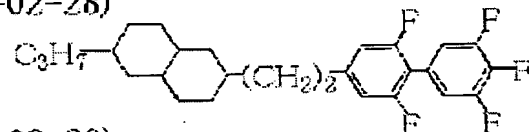
(2-02-26)



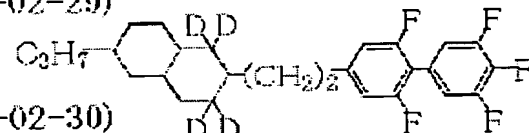
(2-02-27)



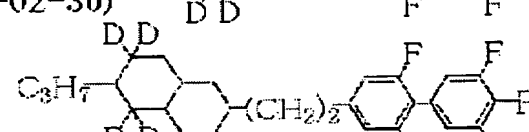
(2-02-28)



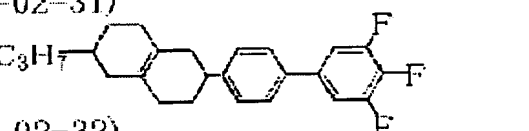
(2-02-29)



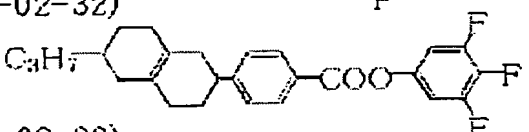
(2-02-30)



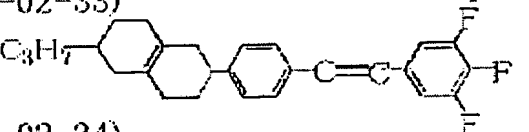
(2-02-31)



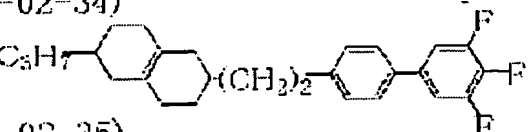
(2-02-32)



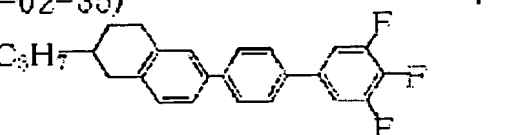
(2-02-33)



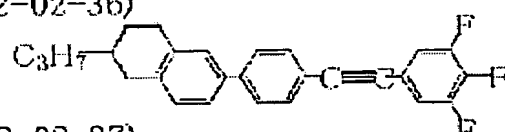
(2-02-34)



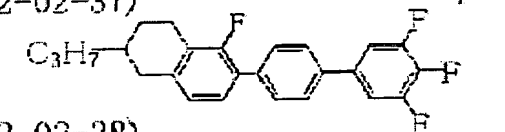
(2-02-35)



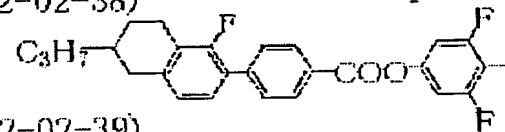
(2-02-36)



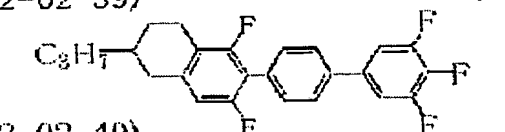
(2-02-37)



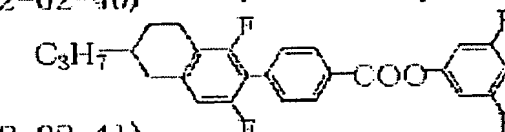
(2-02-38)



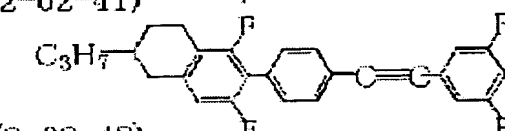
(2-02-39)



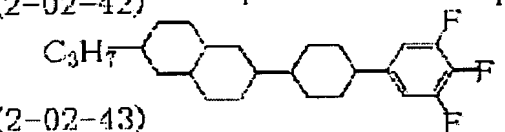
(2-02-40)



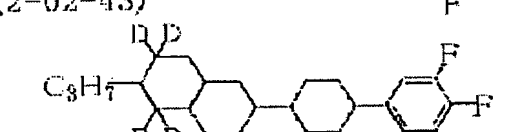
(2-02-41)



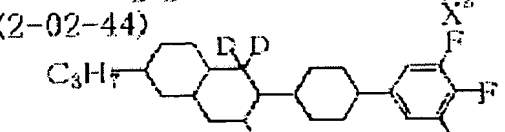
(2-02-42)



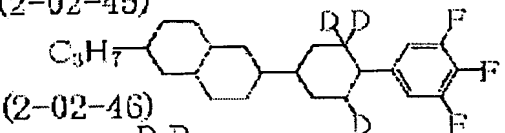
(2-02-43)



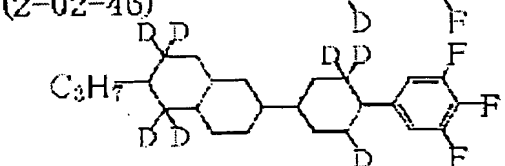
(2-02-44)



(2-02-45)

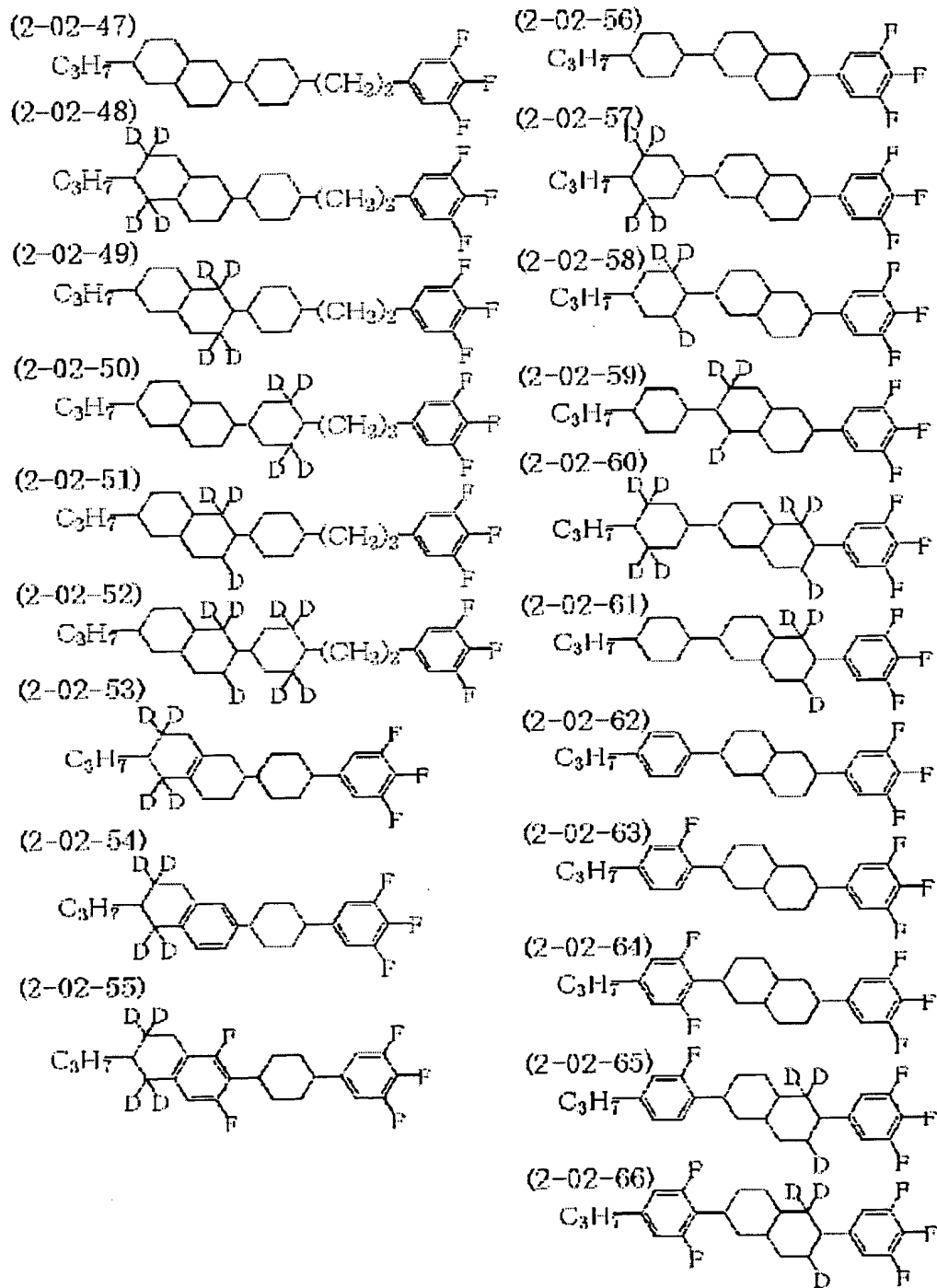


(2-02-46)



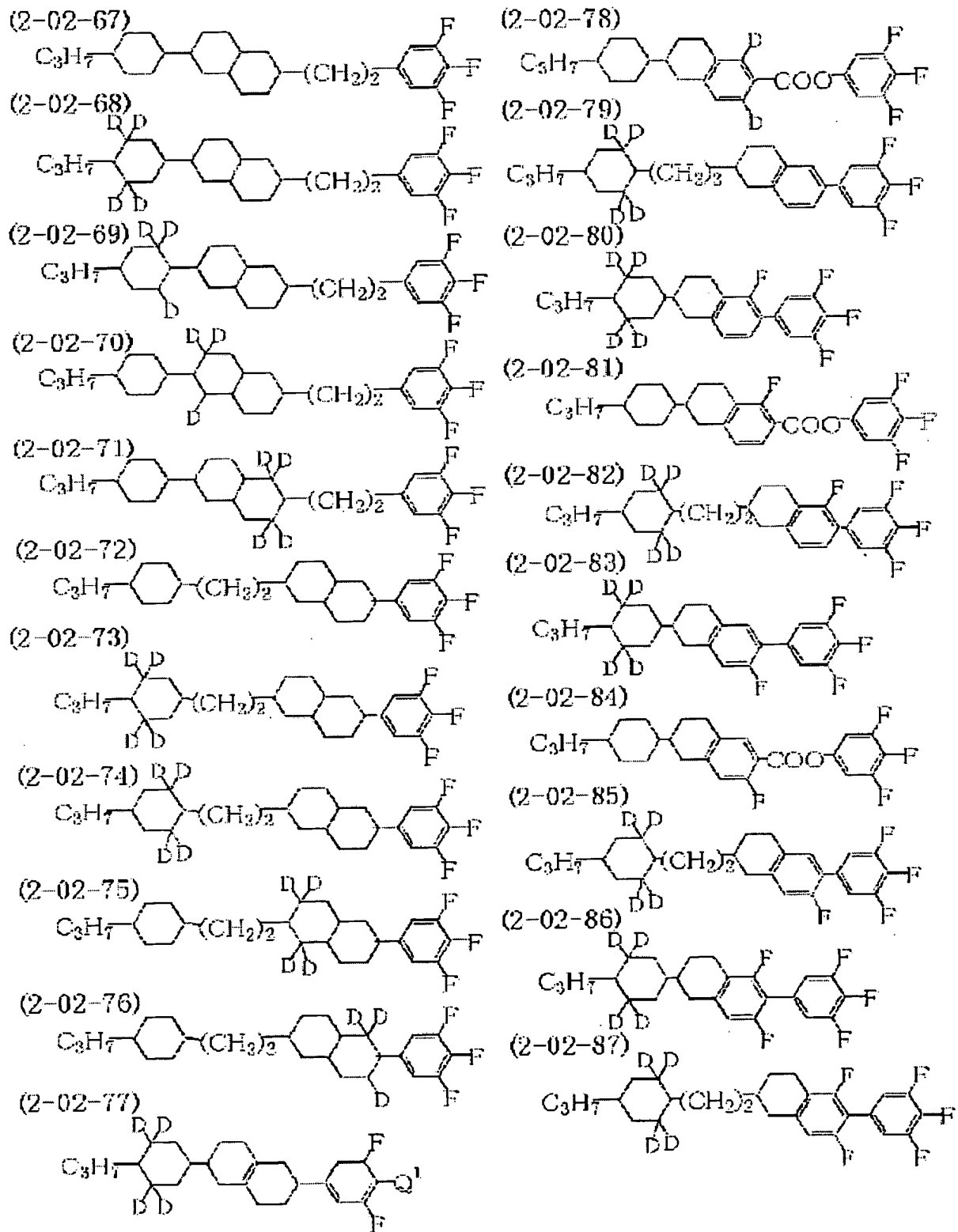
[0281]

[Chemical Formula 92]



[0282]

[Chemical Formula 93]

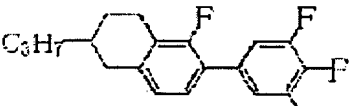
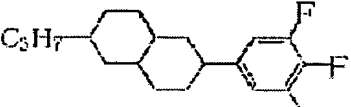
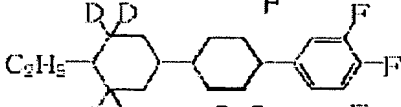
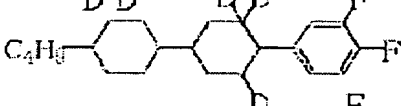

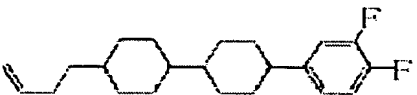
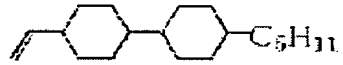
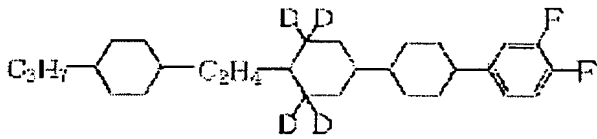


[0283]

(Example 3)

A nematic liquid crystal composition (3-03) was prepared from

[Chemical Formula 94]

(3-0301)		7 wt %
(3-0302)		23 wt %
(3-0303)		11 wt %
(3-0304)		11 wt %
(3-0305)		12 wt %
(3-0306)		11 wt %
(3-0307)		10 wt %
(3-0308)		15 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 85.6°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 5.2

$\Delta n$  : 0.081

Resistivity before heating acceleration test:  $7.6 \times 10^{12}$   
 $\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $3.3 \times 10^{12} \Omega \cdot$   
 cm

Voltage holding ratio before heating acceleration test:  
 99.0%

Voltage holding ratio after heating acceleration test:  
 98.0%

Display characteristics of the TN-LCD having a twist angle of  
 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.44 V

$\gamma$  : 1.30

$\tau_r = \tau_d$ : 52.8 msec.

[0284]

The nematic liquid crystal composition is, despite of being composed of eight kinds of components, capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_N$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is therefore capable of operating even for high resolution display corresponding to a large duty number. Also because this nematic liquid crystal composition has high resistivity and high voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that

employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

[0285]

The following nematic liquid compositions are prepared.

[0286]

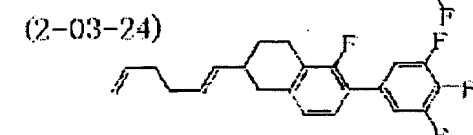
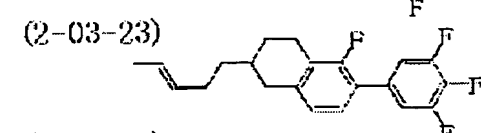
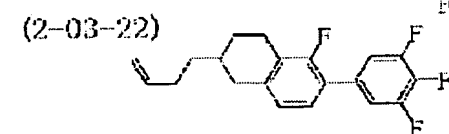
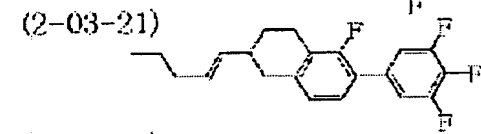
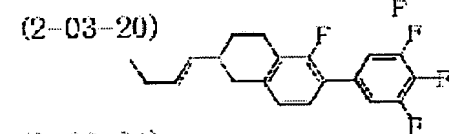
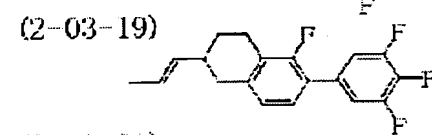
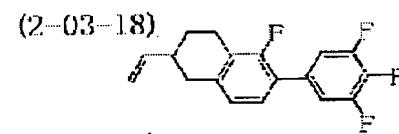
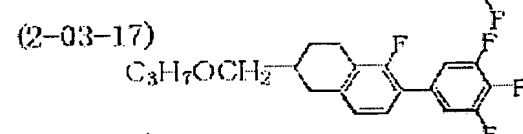
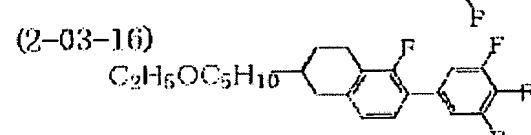
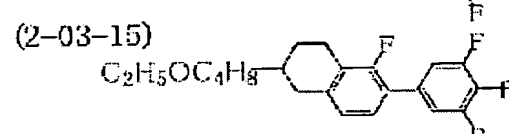
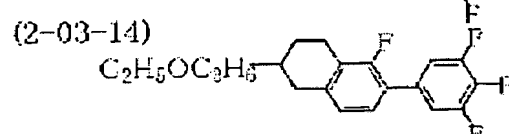
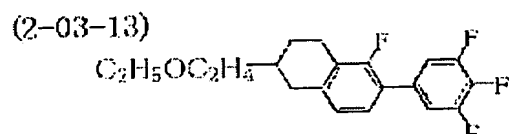
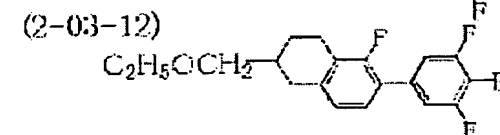
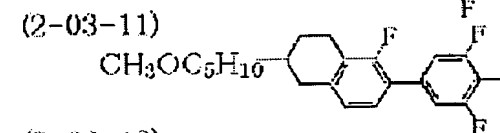
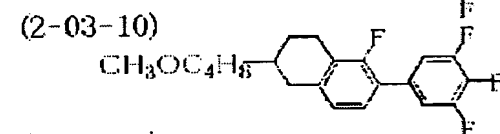
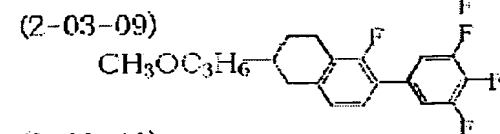
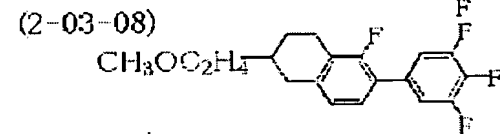
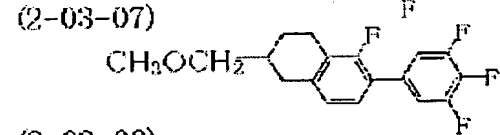
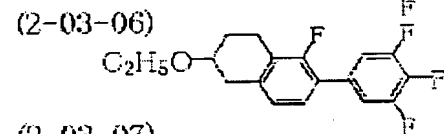
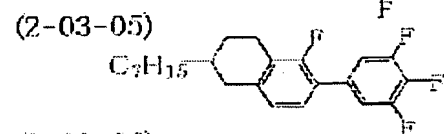
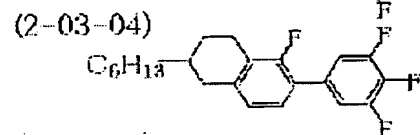
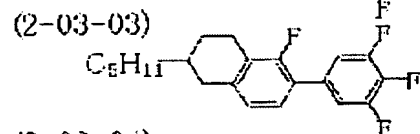
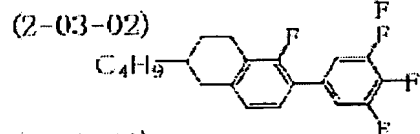
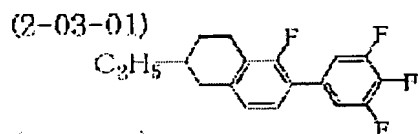
In the same manner as in the case of the nematic liquid crystal composition (3-03), except that the respective compounds (2-03-01) to (2-03-46) described below were used in place of the compound (3-0301) in the nematic liquid crystal composition (3-03) of this Example, nematic liquid crystal compositions (3-03-01) to (3-03-46) were prepared.

[0287]

The display characteristics of these nematic liquid crystal compositions (3-03-01) to (3-03-46) showed good results, similar to this Example.

[0288]

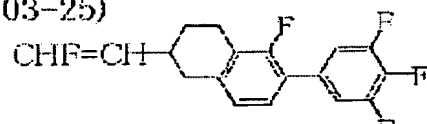
[Chemical Formula 95]



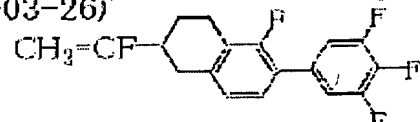
[0289]

[Chemical Formula 96]

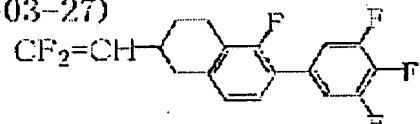
(2-03-25)



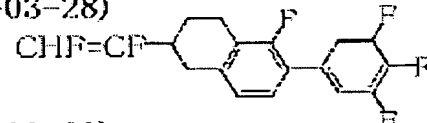
(2-03-26)



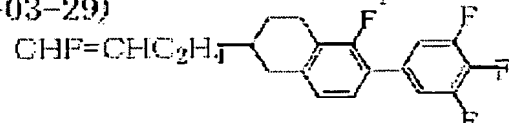
(2-03-27)



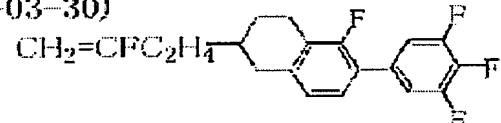
(2-03-28)



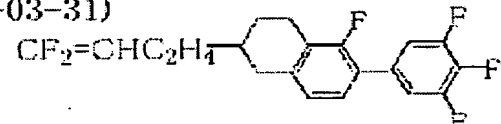
(2-03-29)



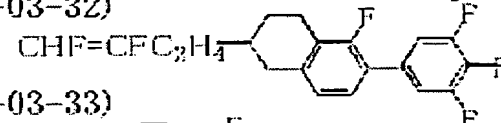
(2-03-30)



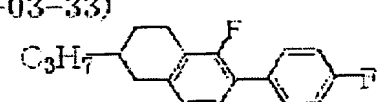
(2-03-31)



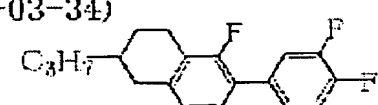
(2-03-32)



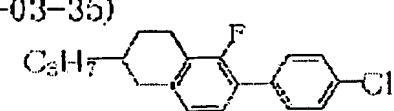
(2-03-33)



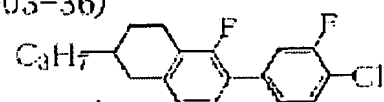
(2-03-34)



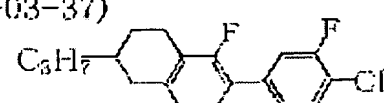
(2-03-35)



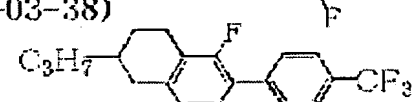
(2-03-36)



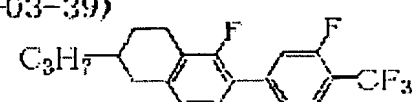
(2-03-37)



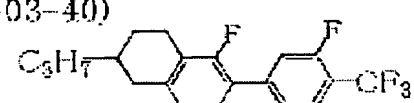
(2-03-38)



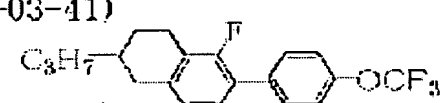
(2-03-39)



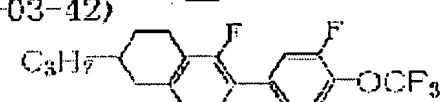
(2-03-40)



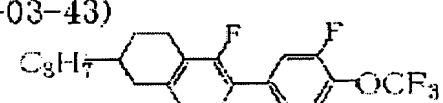
(2-03-41)



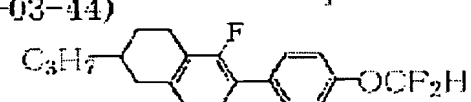
(2-03-42)



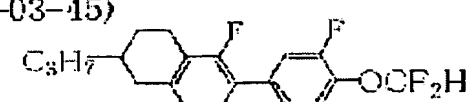
(2-03-43)



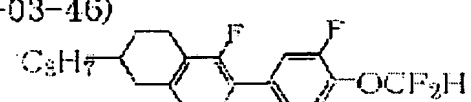
(2-03-44)



(2-03-45)



(2-03-46)





[0290]

(Example 4)

A nematic liquid crystal composition (3-04) was prepared from

[Chemical Formula 97]

(3-0401)		10 wt %
(3-0402)		10 wt %
(3-0403)		10 wt %
(3-0404)		10 wt %
(3-0405)		10 wt %
(3-0406)		5 wt %
(3-0407)		5 wt %
(3-0408)		5 wt %
(3-0409)		5 wt %
(3-0410)		10 wt %
(3-0411)		10 wt %
(3-0412)		10 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 95.0°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 6.9

$\Delta n$  : 0.080

Resistivity before heating acceleration test:  $9.9 \times 10^{12}$

$\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $5.3 \times 10^{12} \Omega \cdot$

cm

Voltage holding ratio before heating acceleration test:

99.1%

Voltage holding ratio after heating acceleration test:

98.5%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.38 V

$\gamma$  : 1.281

[0291]

The nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is therefore capable of operating even for high resolution display corresponding to a large duty number. Also because


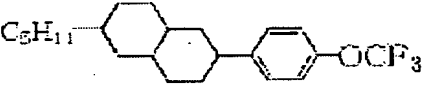
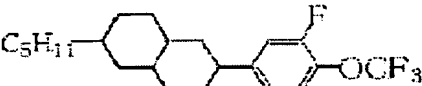
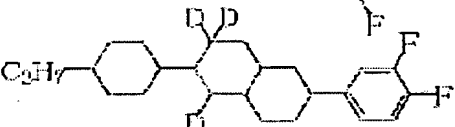
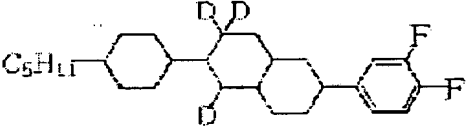
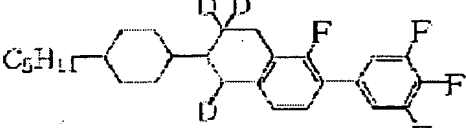

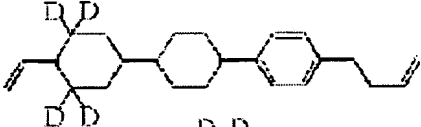
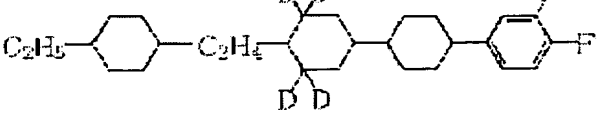
this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

[0292]

(Example 5)

A nematic liquid crystal composition (3-05) was prepared from

[Chemical Formula 98]

(3-0501)		15 wt %
(3-0502)		15 wt %
(3-0503)		10 wt %
(3-0504)		10 wt %
(3-0505)		5 wt %
(3-0506)		15 wt %
(3-0507)		15 wt %
(3-0508)		10 wt %
(3-0509)		5 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

T<sub>N-I</sub> : 86.2°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 4.9

$\Delta n$  : 0.089

$\eta$  : 28.9 c.p.

Resistivity before heating acceleration test:  $1.0 \times 10^{13}$   
 $\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $7.6 \times 10^{12} \Omega \cdot$   
 cm

Voltage holding ratio before heating acceleration test:  
 99.2%

Voltage holding ratio after heating acceleration test:  
 98.6%

Display characteristics of the TN-LCD having a twist angle of  
 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.69 V

$\gamma$  : 1.251

$\tau_r = \tau_d$ : 42.1 msec

[0293]

The nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is therefore capable of operating even for high resolution display corresponding to a large duty number. Also because this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it

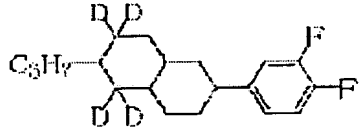

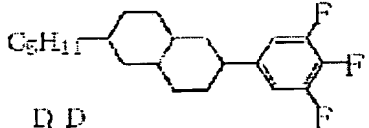
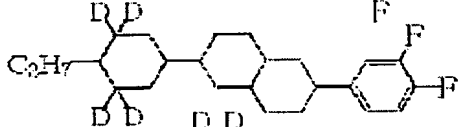
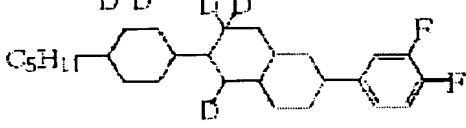
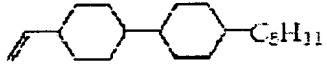
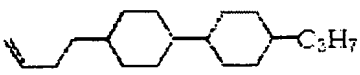
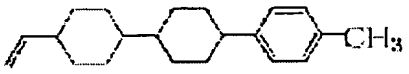
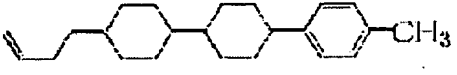
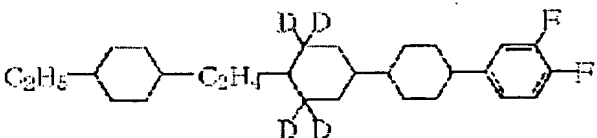
can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

[0294]

(Example 6)

A nematic liquid crystal composition (3-06) was prepared from

[Chemical Formula 99]

(3-0601)		5 wt %
(3-0602)		15 wt %
(3-0603)		10 wt %
(3-0604)		10 wt %
(3-0605)		10 wt %
(3-0606)		10 wt %
(3-0607)		10 wt %
(3-0608)		10 wt %
(3-0609)		10 wt %
(3-0610)		10 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 114.2°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 3.4

$\Delta n$  : 0.078

$\eta$  : 23.9 c.p.

Resistivity before heating acceleration test:  $4.2 \times 10^{13}$

$\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $8.5 \times 10^{12} \Omega \cdot$

cm

Voltage holding ratio before heating acceleration test:

99.5%

Voltage holding ratio after heating acceleration test:

99.0%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 2.29 V

$\gamma$  : 1.288

$\tau_r = \tau_d$ : 36. msec

[0295]

The nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is

therefore capable of operating even for high resolution display corresponding to a large duty number. Also because this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

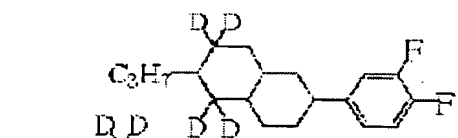
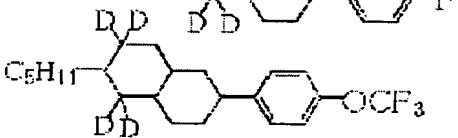
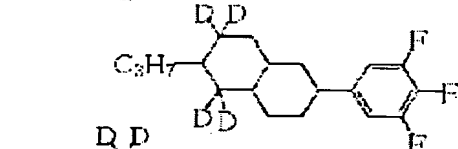
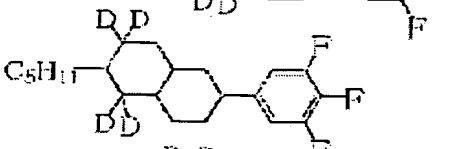
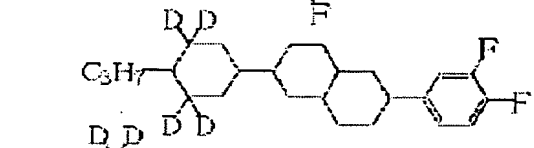
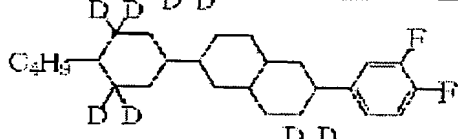
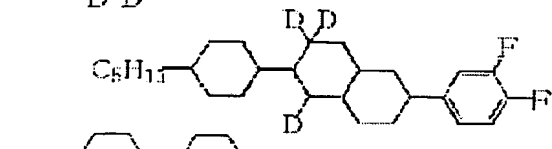
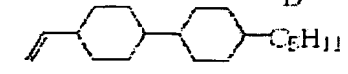
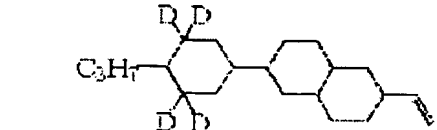


[0296]

(Example 7)

A nematic liquid crystal composition (3-07) was prepared from

[Chemical Formula 100]

(3-0701)		10 wt %
(3-0702)		10 wt %
(3-0703)		10 wt %
(3-0704)		10 wt %
(3-0705)		15 wt %
(3-0706)		10 wt %
(3-0707)		15 wt %
(3-0708)		10 wt %
(3-0709)		15 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 86.3°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 4.2

$\Delta n$  : 0.067

Resistivity before heating acceleration test:  $5.0 \times 10^{13}$

$\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $8.8 \times 10^{12} \Omega \cdot$

cm

Voltage holding ratio before heating acceleration test:

99.6%

Voltage holding ratio after heating acceleration test:

99.5%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 2.29 V

$\gamma$  : 1.284

[0297]

The nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is therefore capable of operating even for high resolution display corresponding to a large duty number. Also because this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The

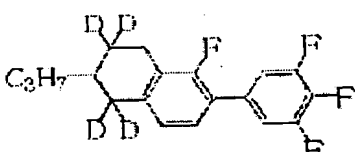
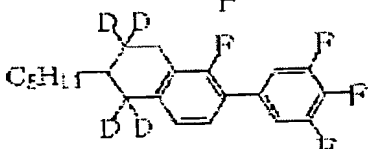
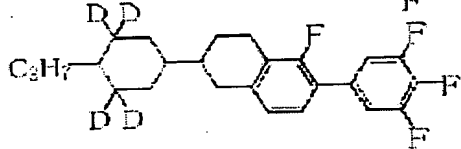
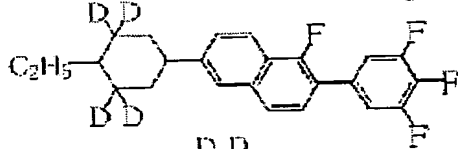
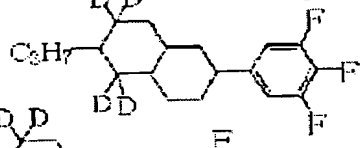
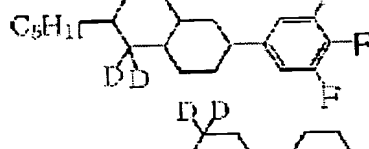
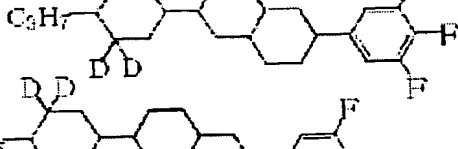
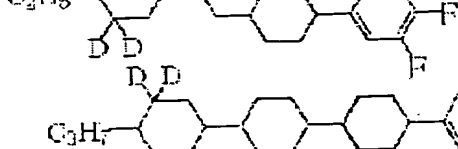
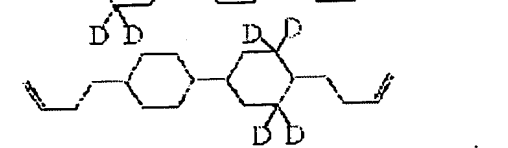
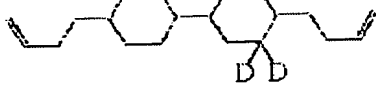
active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

[0298]

(Example 8)

A nematic liquid crystal composition (3-08) was prepared from

[Chemical Formula 101]

(3-0801)		10 wt %
(3-0802)		10 wt %
(3-0803)		10 wt %
(3-0804)		5 wt %
(3-0805)		10 wt %
(3-0806)		10 wt %
(3-0807)		10 wt %
(3-0808)		10 wt %
(3-0809)		10 wt %
(3-0810)		15 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 71.4°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 8.1

$\Delta n$  : 0.089

Voltage holding ratio before heating acceleration test:

99.0%

Voltage holding ratio after heating acceleration test:

98.8%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.12 V

$\gamma$  : 1.256

[0299]

The nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low, and has a low driving voltage compared to the value of dielectric constant anisotropy  $\Delta\epsilon$ , and is therefore capable of operating even for high resolution display corresponding to a large duty number. Also because this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent

characteristics with less leak current without occurrence of flicker.

[0300]

The following nematic liquid compositions are prepared.

[0301]

In the same manner as in the case of the nematic liquid crystal composition (3-08), except that the respective compounds (2-08-01) to (2-08-71) described below were used in place of the compound (3-0803) in the nematic liquid crystal composition (3-08) of this Example, nematic liquid crystal compositions (3-08-01) to (3-08-71) were prepared.

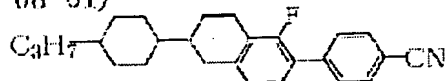
[0302]

The display characteristics of these nematic liquid crystal compositions (3-08-01) to (3-08-71) showed good results, similar to this Example.

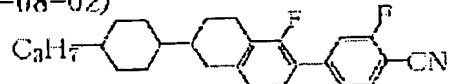
[0303]

[Chemical Formula 102]

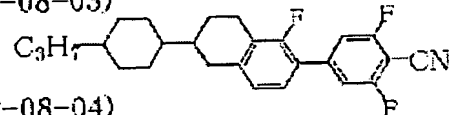
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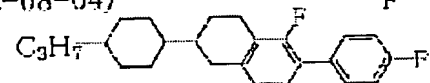
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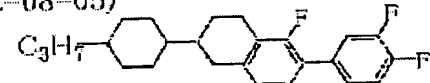
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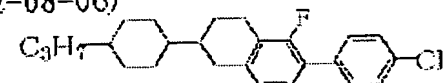
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(2-08-05)



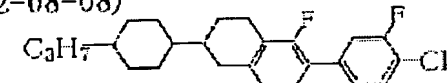
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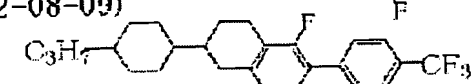
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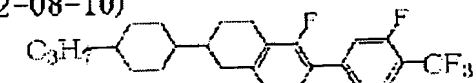
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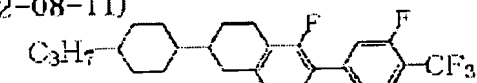
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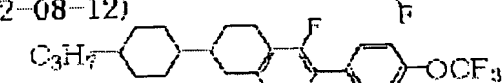
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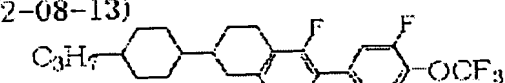
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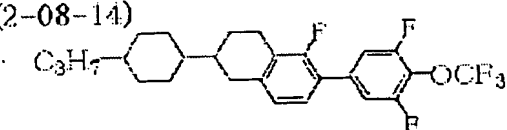
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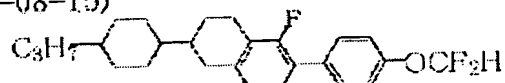
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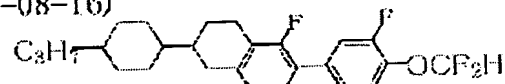
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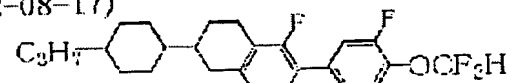
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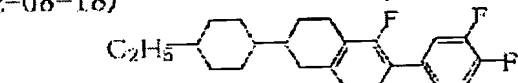
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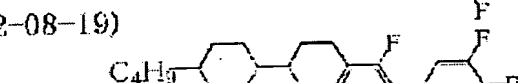
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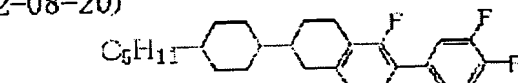
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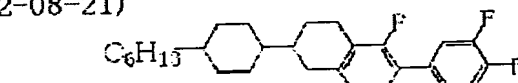
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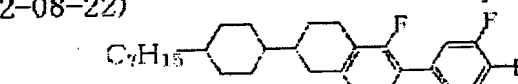
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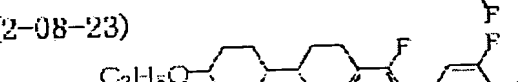
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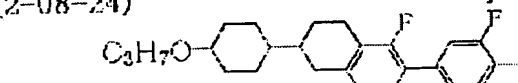
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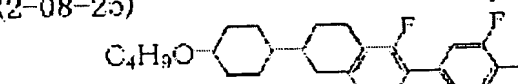
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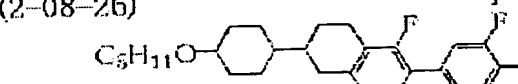
(2-08-24)



(2-08-25)



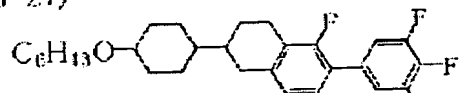
(2-08-26)



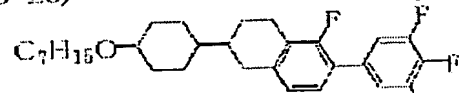
[0304]

[Chemical Formula 103]

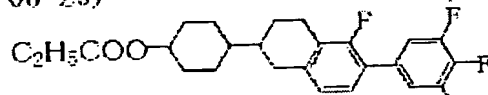
(2-08-27)



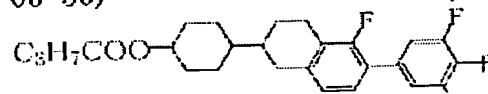
(2-08-28)



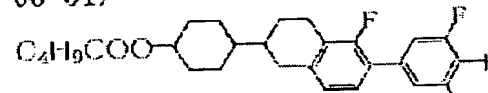
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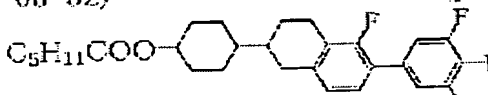
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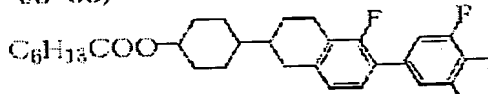
(2-08-31)



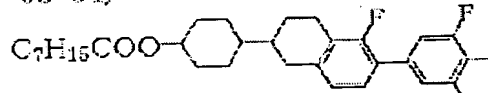
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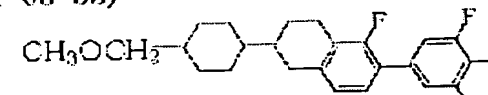
(2-08-33)



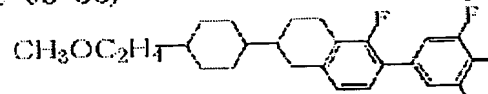
(2-08-34)



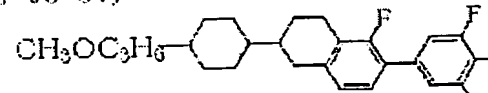
(2-08-35)



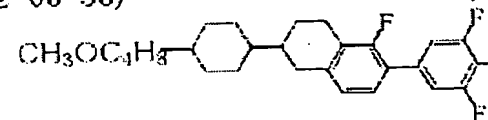
(2-08-36)



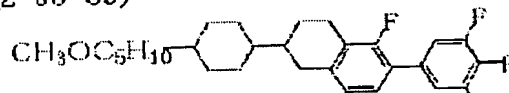
(2-08-37)



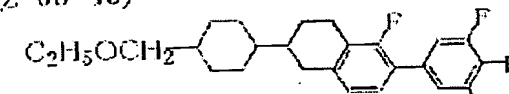
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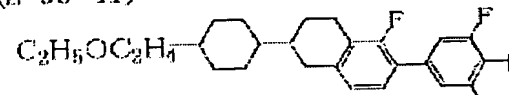
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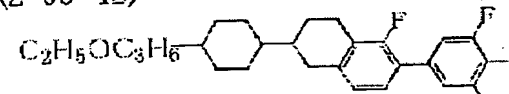
(2-08-40)



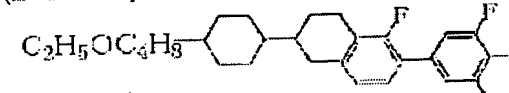
(2-08-41)



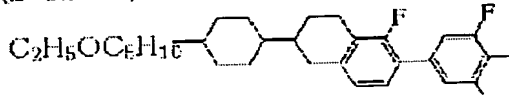
(2-08-42)



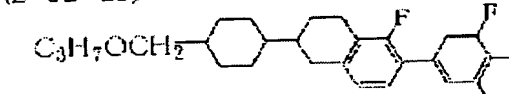
(2-08-43)



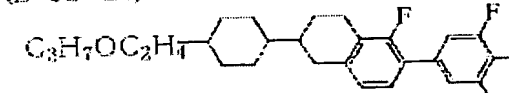
(2-08-44)



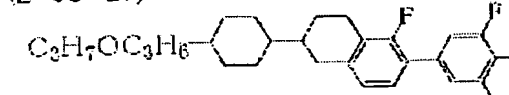
(2-08-45)



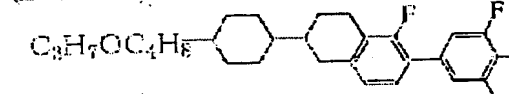
(2-08-46)



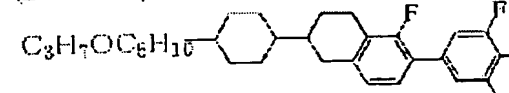
(2-08-47)



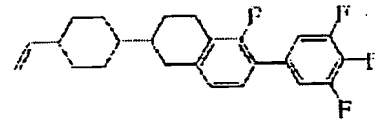
(2-08-48)



(2-08-49)



(2-08-50)

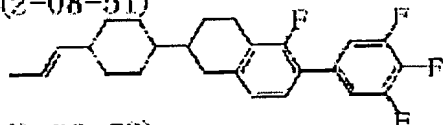




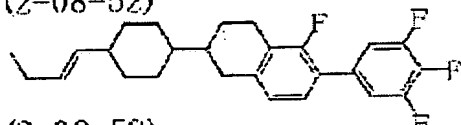
[0305]

[Chemical Formula 104]

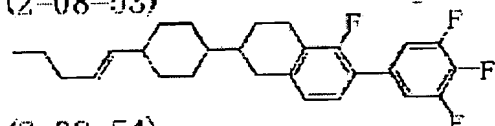
(2-08-51)



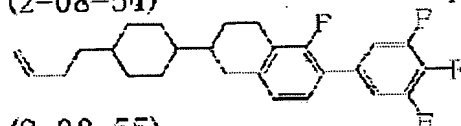
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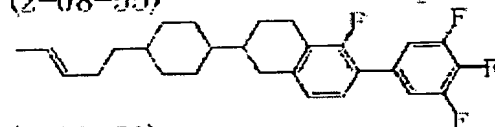
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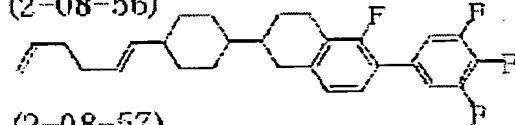
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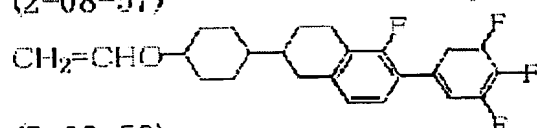
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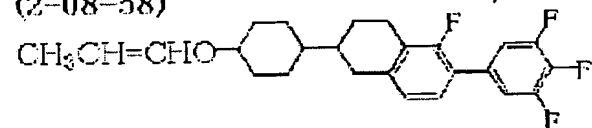
(2-08-56)



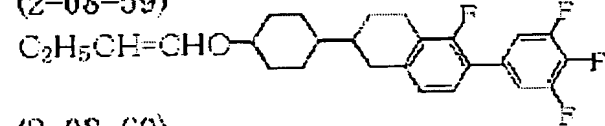
(2-08-57)



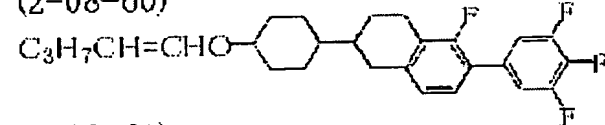
(2-08-58)



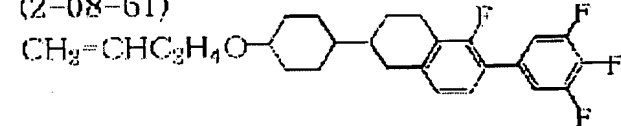
(2-08-59)



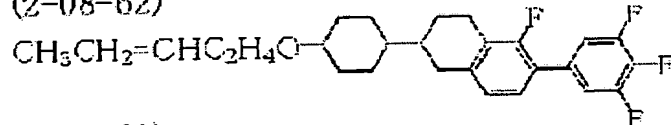
(2-08-60)



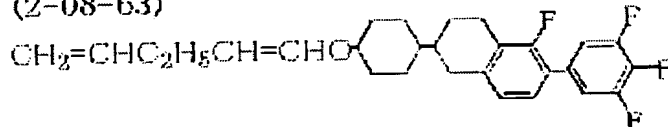
(2-08-61)



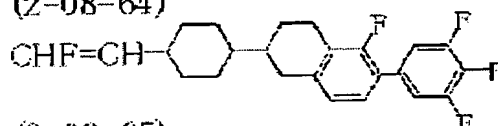
(2-08-62)



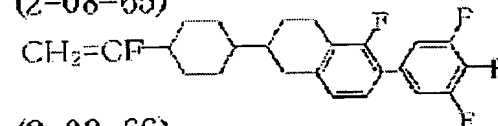
(2-08-63)



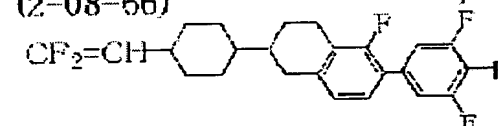
(2-08-64)



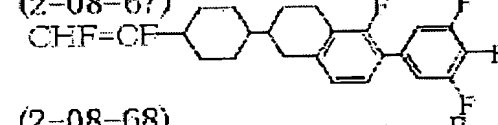
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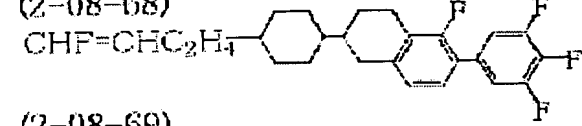
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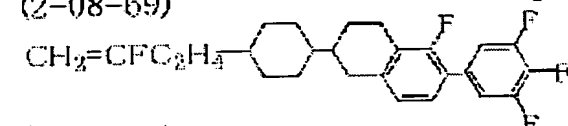
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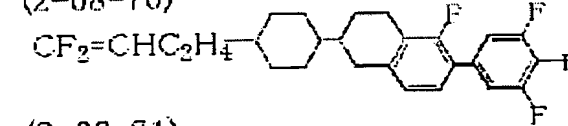
(2-08-68)



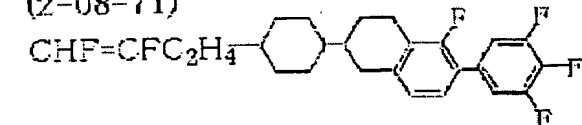
(2-08-69)



(2-08-70)



(2-08-71)

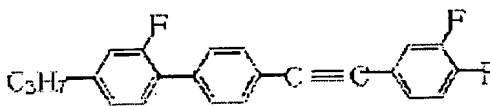
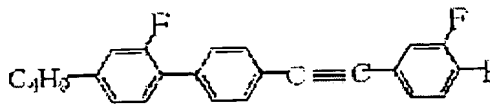
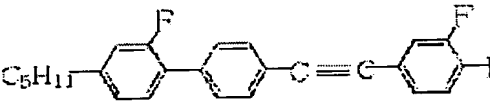
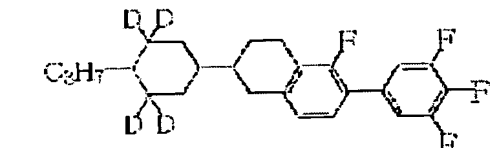
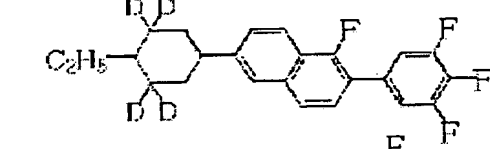
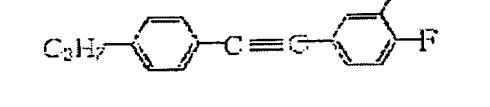
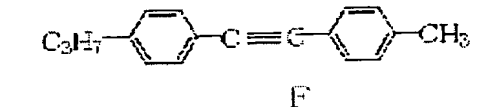
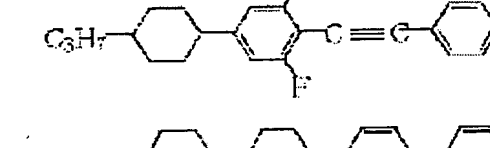



[0306]

(Example 9)

A nematic liquid crystal composition (3-09) was prepared from

[Chemical Formula 105]

(3-0901)		15 wt %
(3-0902)		15 wt %
(3-0903)		15 wt %
(3-0904)		10 wt %
(3-0905)		5 wt %
(3-0906)		10 wt %
(3-0907)		15 wt %
(3-0908)		13 wt %
(3-0909)		2 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 100.2°C

$T_{-N}$  : -40. °C

$\Delta\epsilon$  : 7.1

$\Delta n$  : 0.268

Voltage holding ratio before heating acceleration test:

98.9%

Voltage holding ratio after heating acceleration test:

98.0%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 2.09 V

$\gamma$  : 1.148

[0307]

The nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low, and also has a large value of  $\Delta n$ , and is therefore capable of improving the response speed. Also because this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker.

[0308]

This nematic liquid crystal composition shows a value of optical sharpness near 1.12 that is the limit of TN-LCD liquid

crystal shown in the literature "High-speed Liquid Crystal Technology" (p.63, CMC Publication). Thus it can be understood that this liquid crystal composition is useful for high-frequency multiplexing drive.

[0309]

This nematic liquid crystal composition was used to make TN-LCD having cell thickness  $d$  of 1.9  $\mu\text{m}$  and display characteristics thereof were measured. A liquid crystal display device having a threshold voltage of 1.67 V and a response speed of 2.6 msec. was obtained.

[0311]

The following nematic liquid compositions are prepared.

[0311]

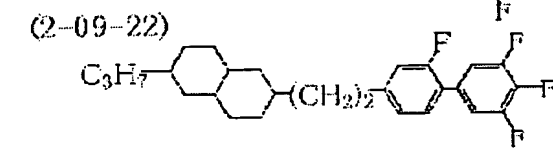
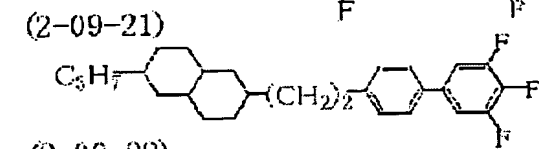
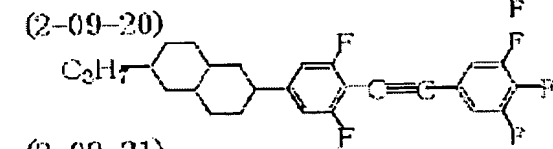
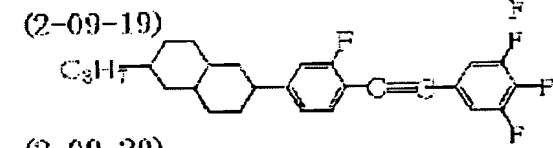
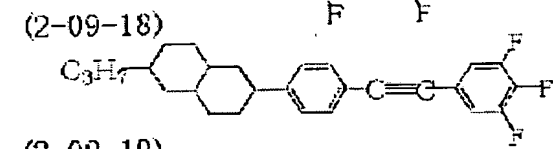
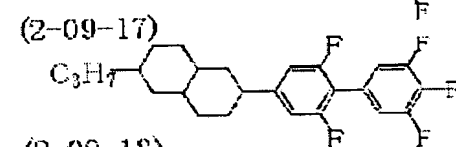
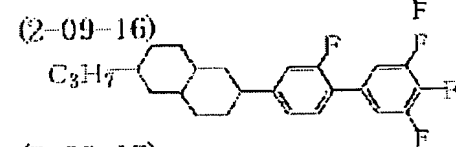
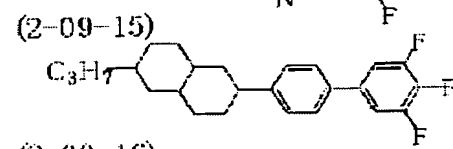
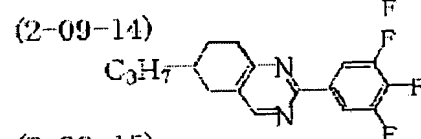
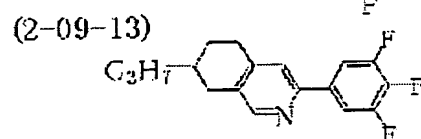
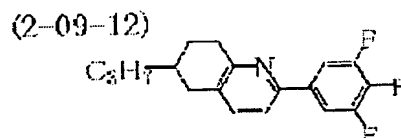
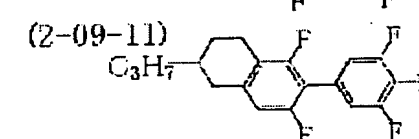
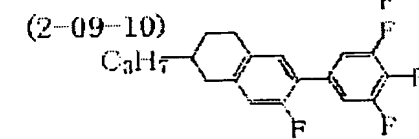
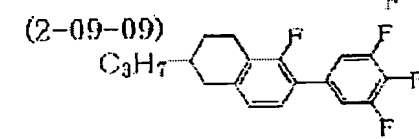
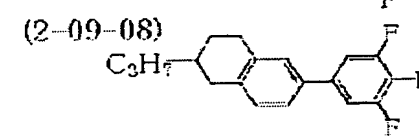
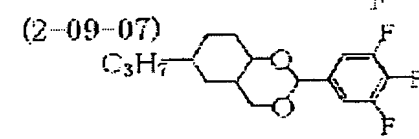
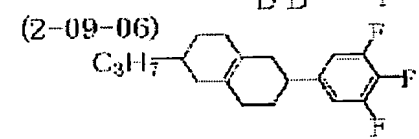
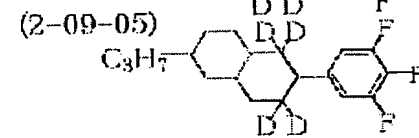
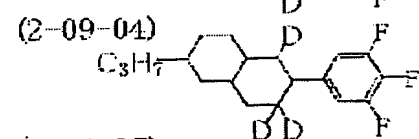
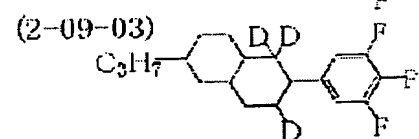
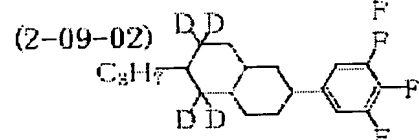
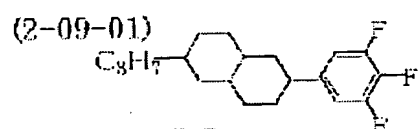
In the same manner as in the case of the nematic liquid crystal composition (3-09), except that the respective compounds (2-09-01) to (2-09-38) were used in place of the compound (3-0904) in the nematic liquid crystal composition (3-09) of this Example, nematic liquid crystal compositions (3-09-01) to (3-09-38) were prepared.

[0312]

The display characteristics of these nematic liquid crystal compositions (3-39-01) to (3-09-38) showed good results, similar to this Example.

[0313]

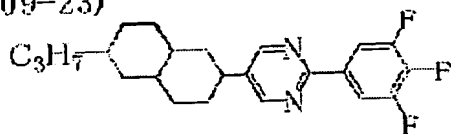
[Chemical Formula 106]



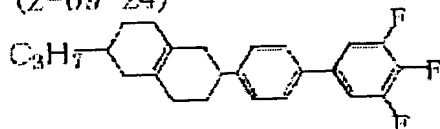
[0314]

[Chemical Formula 107]

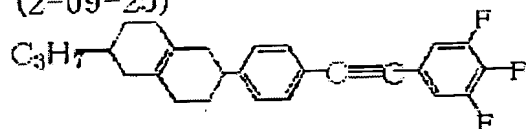
(2-09-23)



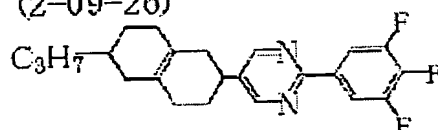
(2-09-24)



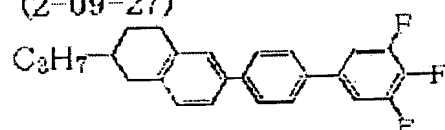
(2-09-25)



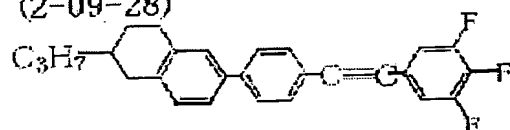
(2-09-26)



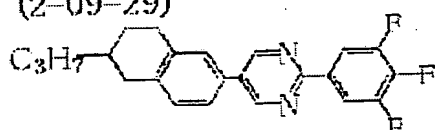
(2-09-27)



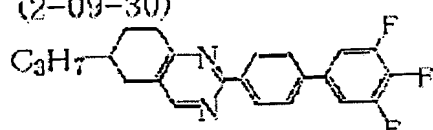
(2-09-28)



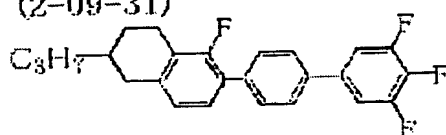
(2-09-29)



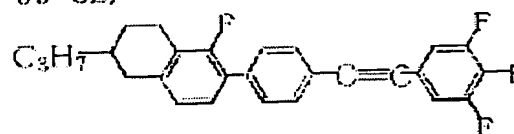
(2-09-30)



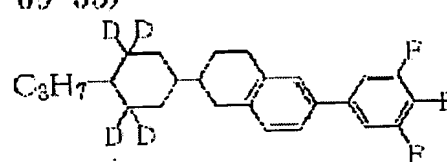
(2-09-31)



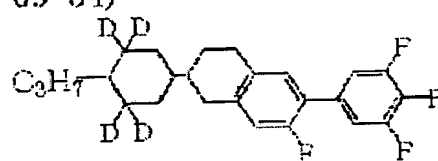
(2-09-32)



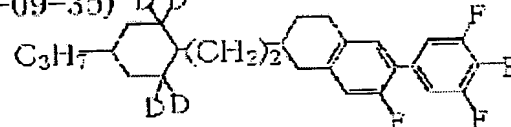
(2-09-33)



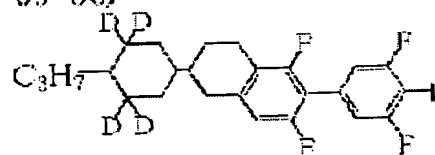
(2-09-34)



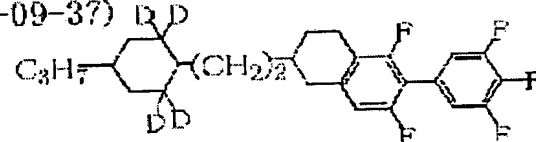
(2-09-35)



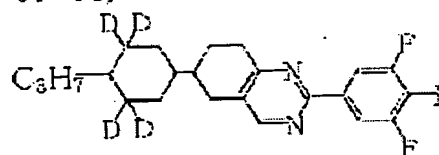
(2-09-36)



(2-09-37)



(2-09-38)

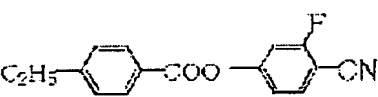
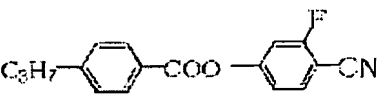
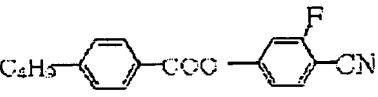
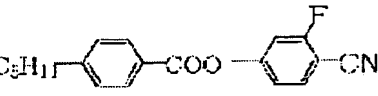
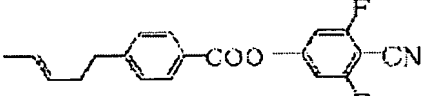
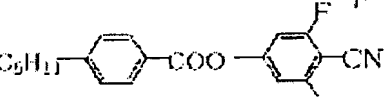
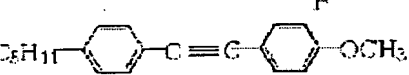
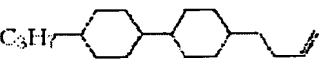
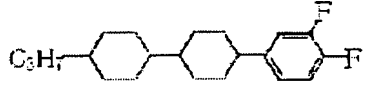
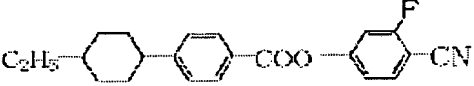
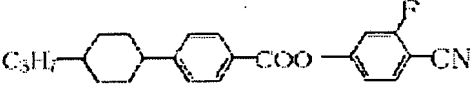
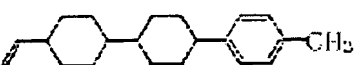
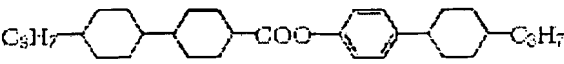
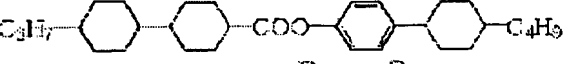
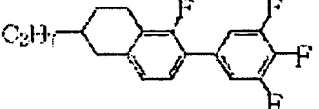


[0315]

(Example 10)

A nematic liquid crystal composition (3-10) was prepared from

[Chemical Formula 108]

(3-1001)		8 wt %
(3-1002)		5 wt %
(3-1003)		16 wt %
(3-1004)		7 wt %
(3-1005)		5 wt %
(3-1006)		5 wt %
(3-1007)		2 wt %
(3-1008)		2 wt %
(3-1009)		17 wt %
(3-1010)		5 wt %
(3-1011)		5 wt %
(3-1012)		7 wt %
(3-1013)		3 wt %
(3-1014)		3 wt %
(3-1015)		7 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 74.6°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 26.1

$\Delta n$  : 0.141

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 0.79 V

$\gamma$  : 1.121

$\tau_{r=id}$ : 40. msec

Display characteristics of the STN-LCD having a twist angle of 240 degrees

$V_{th}$  : 0.87 V

$\gamma$  : 1.030

$\Delta(V_{th})/\Delta(T)$  : 1.9 mV/°C ( $T=5$  to 40°C)

[0316]

The STN liquid crystal display device having a twist angle of 240 degrees had a driving voltage of 1 V or less, and also exhibited small concentration dependency of the driving voltage, fast response characteristics, and display characteristic which are superior in high-frequency time division characteristic due to sharpness.

[0317]

The following nematic liquid compositions are prepared.

[0318]



In the same manner as in the case of the nematic liquid crystal composition (3-10), except that the respective compounds (2-10-01) to (2-10-90) described below were used in place of the compound (3-1015) in the nematic liquid crystal composition (3-10) of this Example, nematic liquid crystal compositions (3-10-01) to (3-10-90) were prepared.

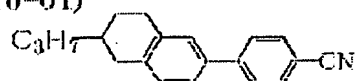
[0319]

The display characteristics of these nematic liquid crystal compositions (3-10-01) to (3-10-01) showed good results, similar to this Example.

[0320]

[Chemical Formula 109]

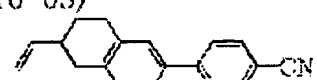
(2-10-01)



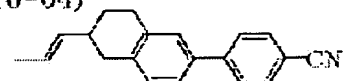
(2-10-02)



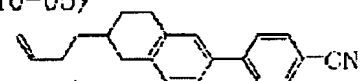
(2-10-03)



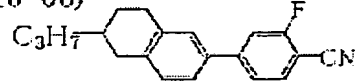
(2-10-04)



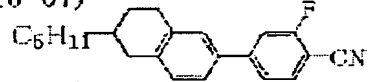
(2-10-05)



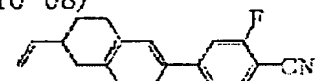
(2-10-06)



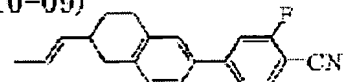
(2-10-07)



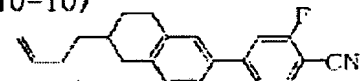
(2-10-08)



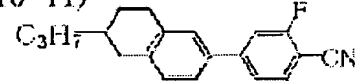
(2-10-09)



(2-10-10)



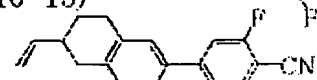
(2-10-11)



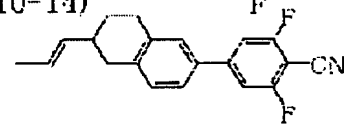
(2-10-12)



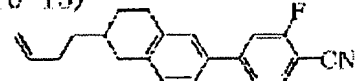
(2-10-13)



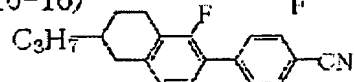
(2-10-14)



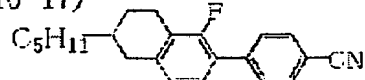
(2-10-15)



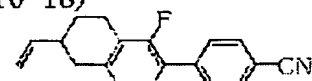
(2-10-16)



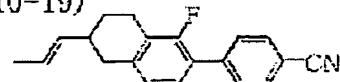
(2-10-17)



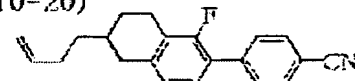
(2-10-18)



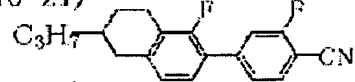
(2-10-19)



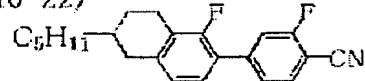
(2-10-20)



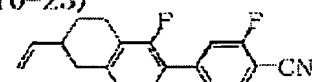
(2-10-21)



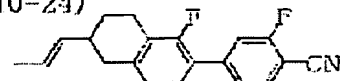
(2-10-22)



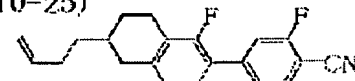
(2-10-23)



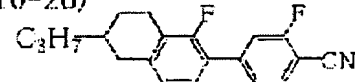
(2-10-24)



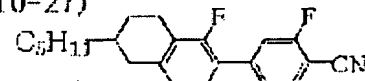
(2-10-25)



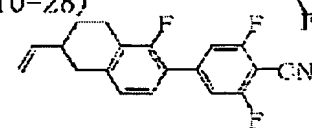
(2-10-26)



(2-10-27)

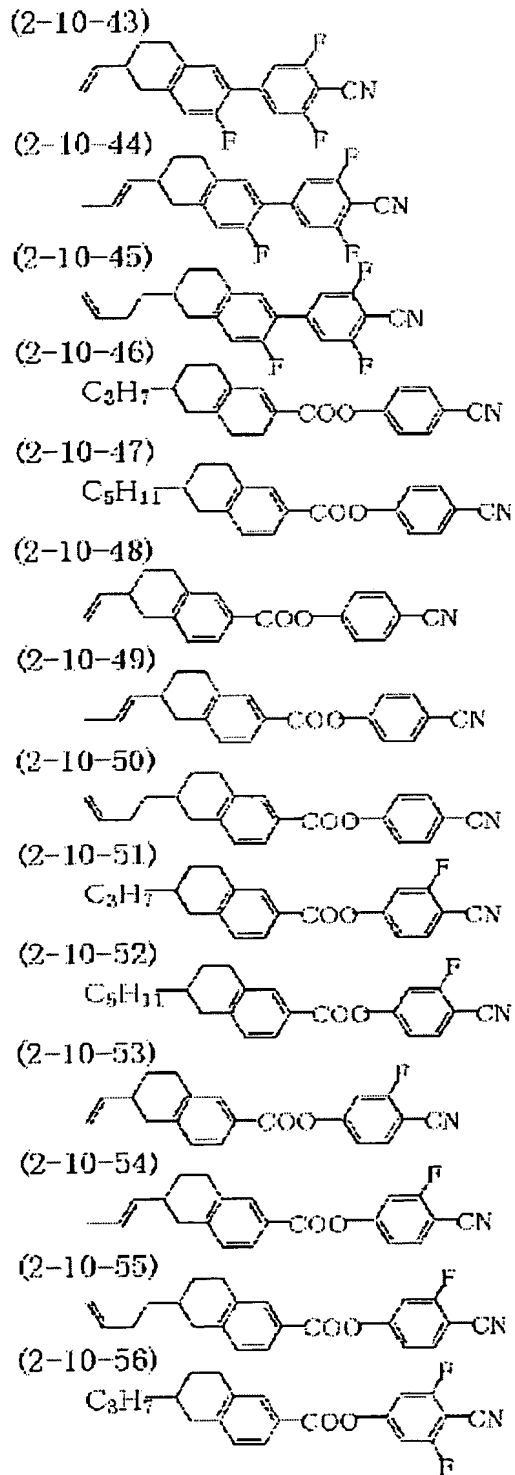
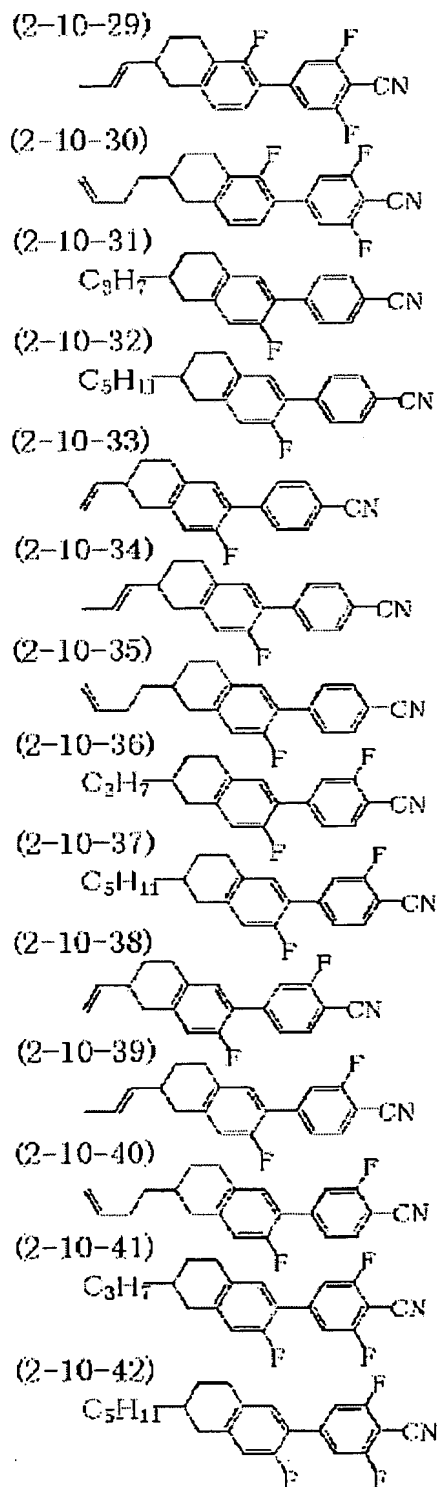


(2-10-28)



[0321]

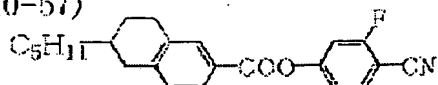
[Chemical Formula 110]



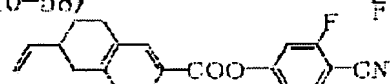
[0322]

[Chemical Formula 111]

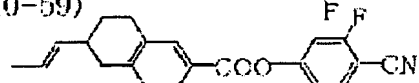
(2-10-57)



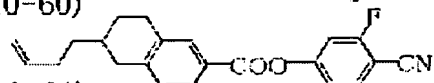
(2-10-58)



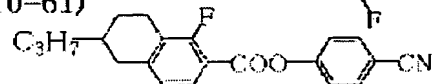
(2-10-59)



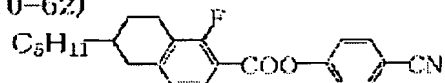
(2-10-60)



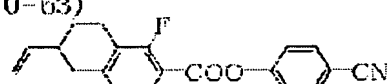
(2-10-61)



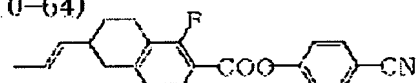
(2-10-62)



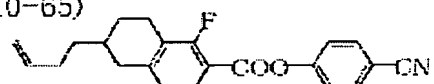
(2-10-63)



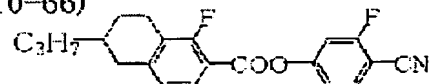
(2-10-64)



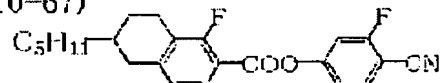
(2-10-65)



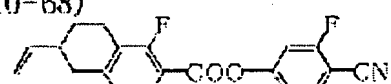
(2-10-66)



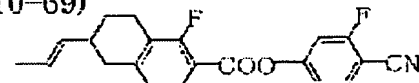
(2-10-67)



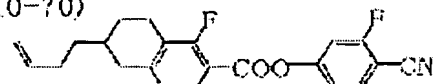
(2-10-68)



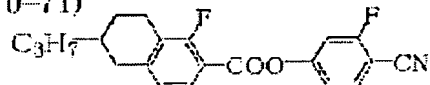
(2-10-69)



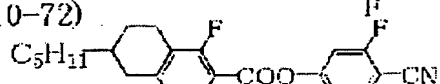
(2-10-70)



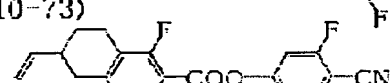
(2-10-71)



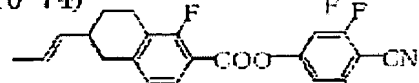
(2-10-72)



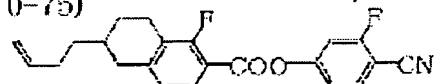
(2-10-73)



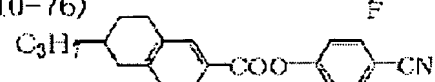
(2-10-74)



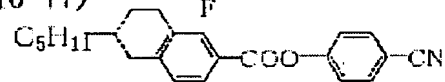
(2-10-75)



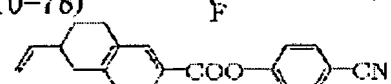
(2-10-76)



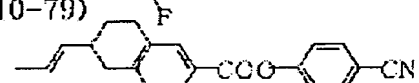
(2-10-77)



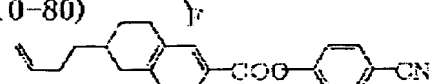
(2-10-78)



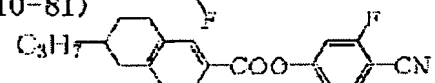
(2-10-79)



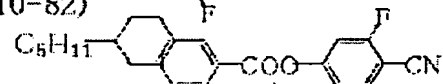
(2-10-80)



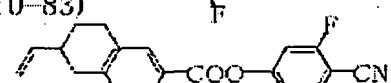
(2-10-81)



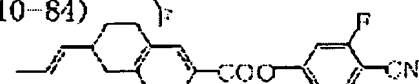
(2-10-82)



(2-10-83)



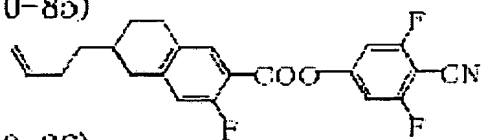
(2-10-84)



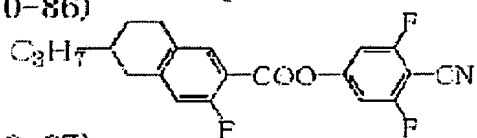
[0323]

[Chemical Formula 112]

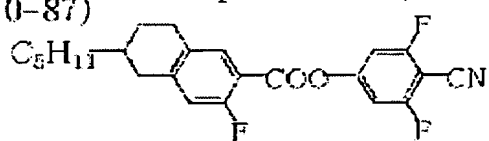
(2-10-85)



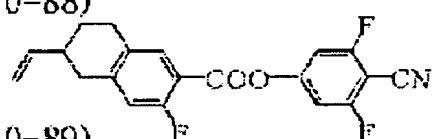
(2-10-86)



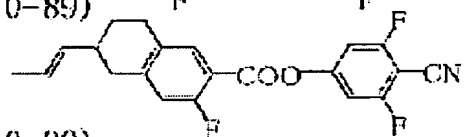
(2-10-87)



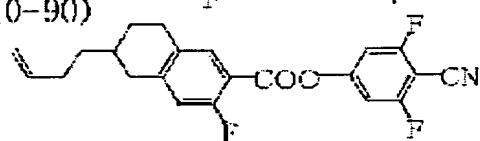
(2-10-88)



(2-10-89)



(2-10-90)

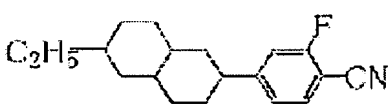
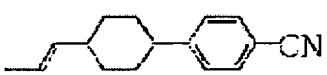
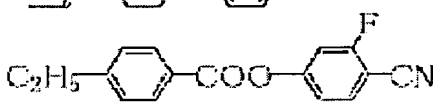
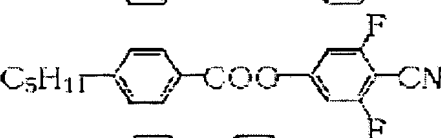

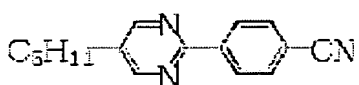
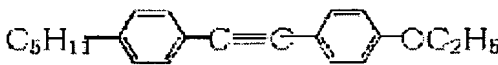
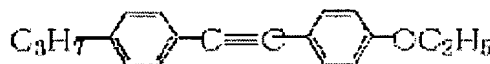



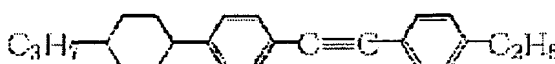



[0324]

(Example 11)

A nematic liquid crystal composition (3-11) was prepared from

[Chemical Formula 113]

(3-1101)		5 wt %
(3-1102)		5 wt %
(3-1103)		5 wt %
(3-1104)		5 wt %
(3-1105)		5 wt %
(3-1106)		5 wt %
(3-1107)		10 wt %
(3-1108)		10 wt %
(3-1109)		20 wt %
(3-1110)		13 wt %
(3-1111)		7 wt %
(3-1112)		5 wt %
(3-1113)		5 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 87.5°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 9.8

$\Delta n$  : 0.162

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.86 V

$\gamma$  : 1.16

Display characteristics of the STN-LCD having a twist angle of 240 degrees

$V_{th}$  : 1.99 V

$\gamma$  : 1.021

$\Delta(V_{th})/\Delta(T)$  : 2.2 mV/°C (T=5 to 40°C)

[0325]

The STN liquid crystal display device having a twist angle of 240 degrees exhibited small concentration dependency of the driving voltage and fast response characteristics and also exhibited display characteristics which are superior in high-frequency time division characteristic due to sharpness.

[0326]

The following nematic liquid compositions are prepared.

[0327]

In the same manner as in the case of the nematic liquid crystal composition (3-11), except that the respective compounds (2-11-01) to (2-11-90) described were used in place of the compound (3-1101) in the nematic liquid crystal

composition (3-11) of this Example, nematic liquid crystal compositions (3-11-01) to (3-11-90) were prepared.

[0328]

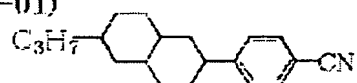
The display characteristics of these nematic liquid crystal compositions (3-11-01) to (3-11-90) showed good results, similar to this Example.



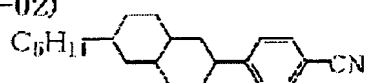
[0329]

[Chemical Formula 114]

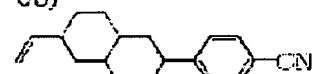
(2-11-01)



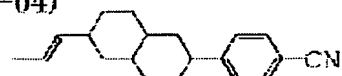
(2-11-02)



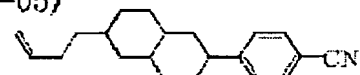
(2-11-03)



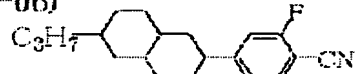
(2-11-04)



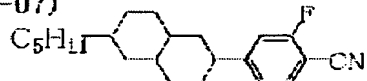
(2-11-05)



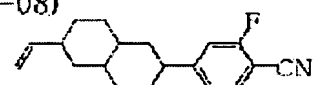
(2-11-06)



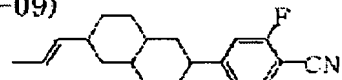
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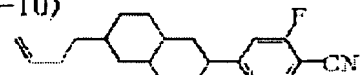
(2-11-08)



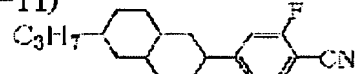
(2-11-09)



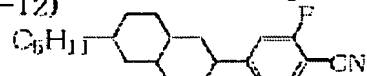
(2-11-10)



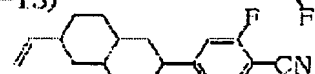
(2-11-11)



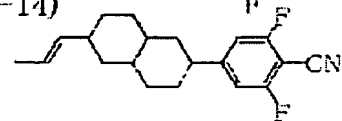
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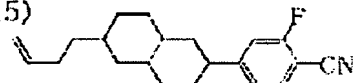
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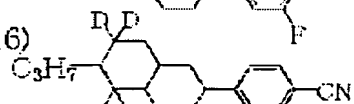
(2-11-14)



(2-11-15)



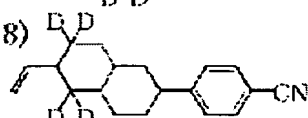
(2-11-16)



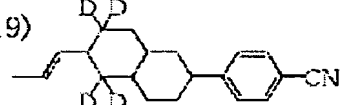
(2-11-17)



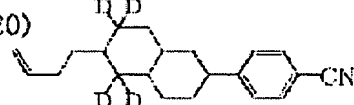
(2-11-18)



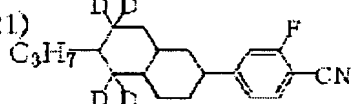
(2-11-19)



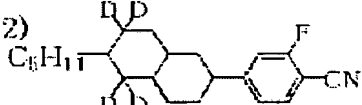
(2-11-20)



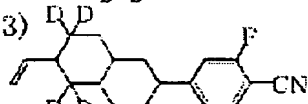
(2-11-21)



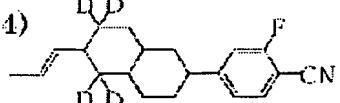
(2-11-22)



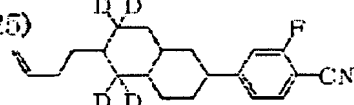
(2-11-23)



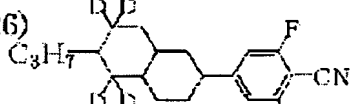
(2-11-24)



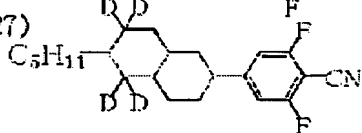
(2-11-25)



(2-11-26)

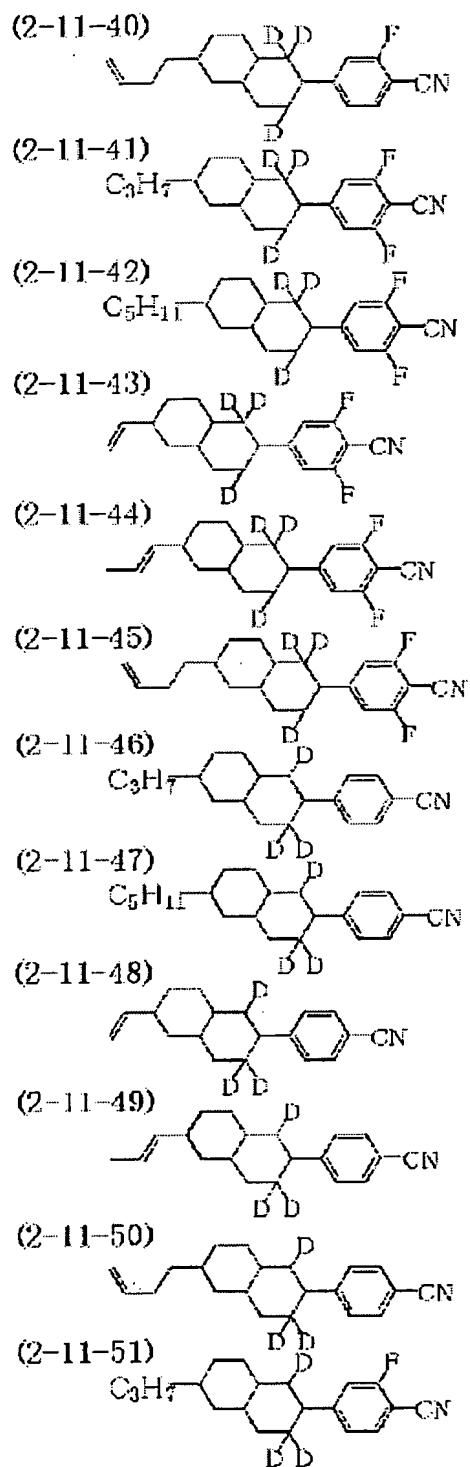
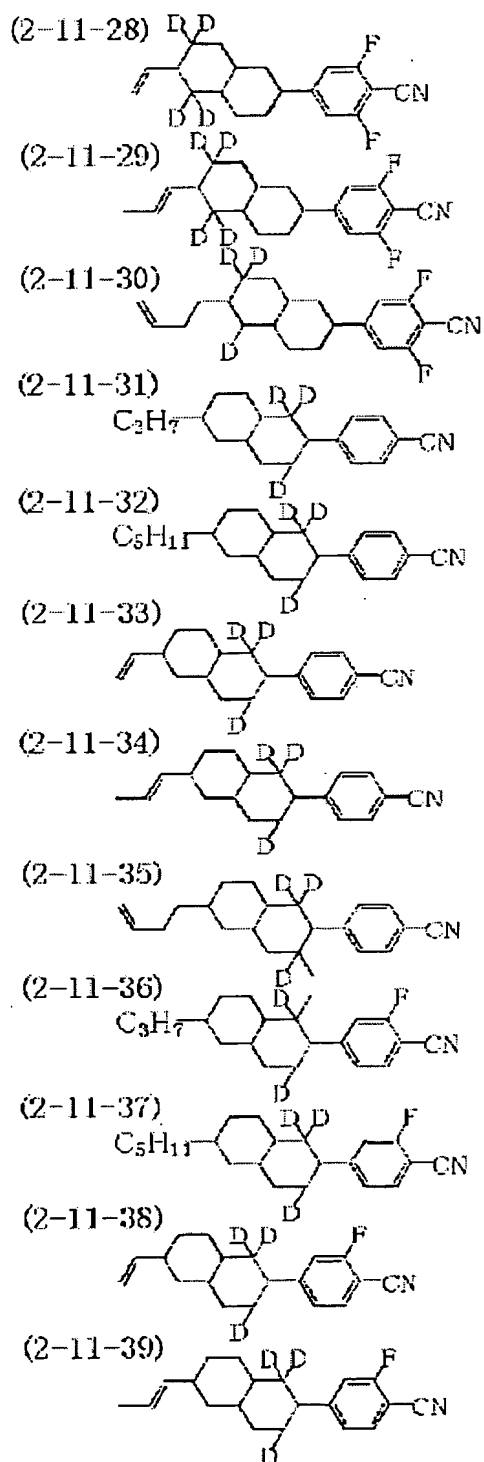


(2-11-27)



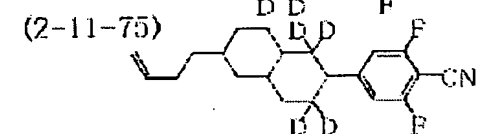
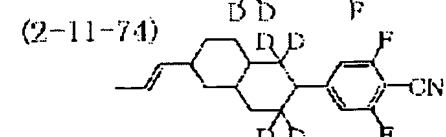
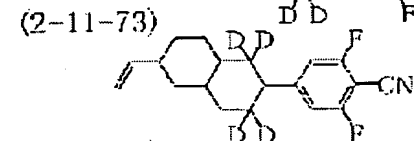
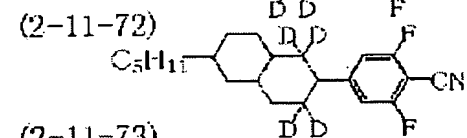
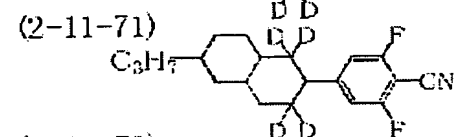
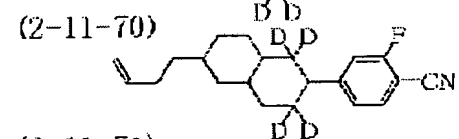
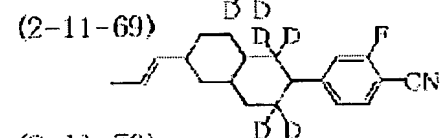
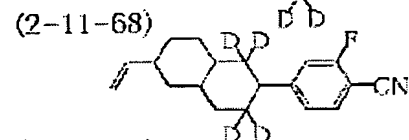
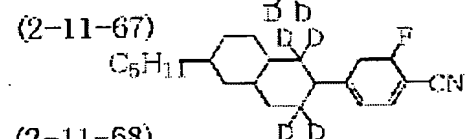
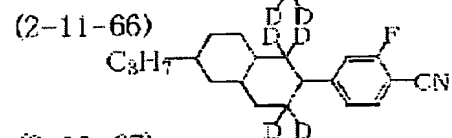
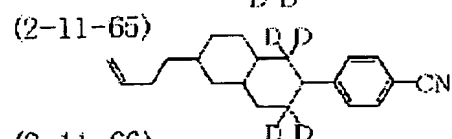
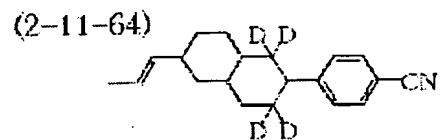
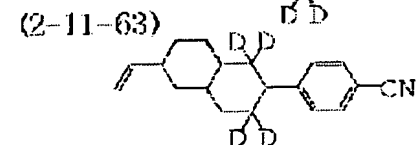
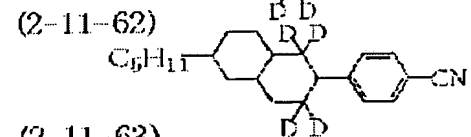
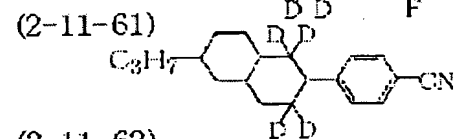
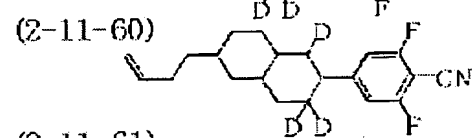
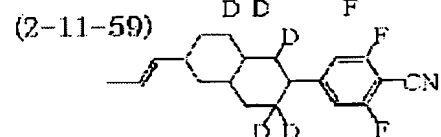
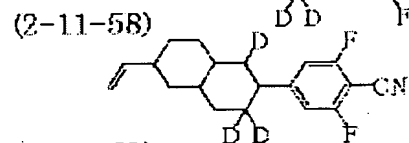
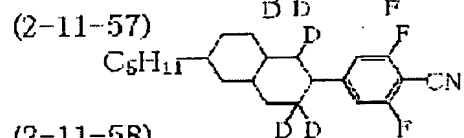
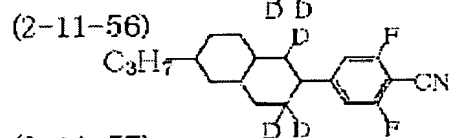
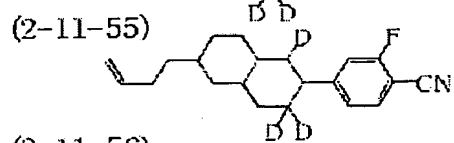
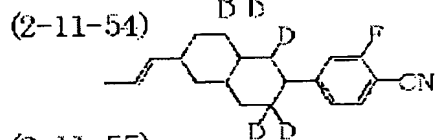
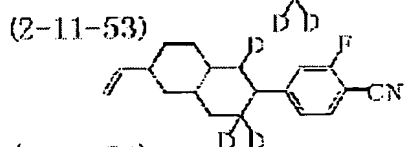
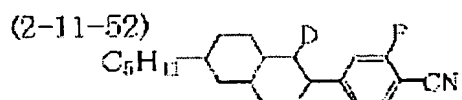
[0330]

[Chemical Formula 115]



[0331]

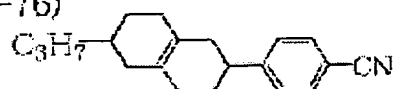
[Chemical Formula 116]



[0332]

[Chemical Formula 117]

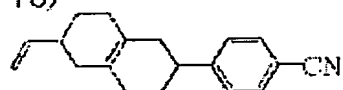
(2-11-76)



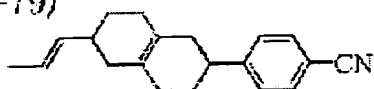
(2-11-77)



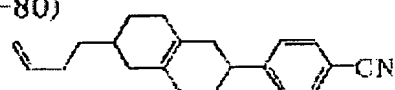
(2-11-78)



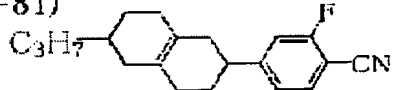
(2-11-79)



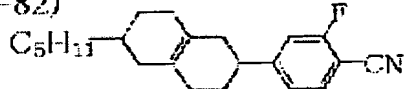
(2-11-80)



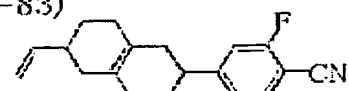
(2-11-81)



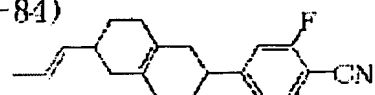
(2-11-82)



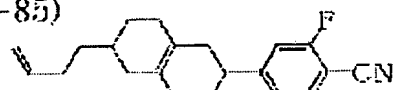
(2-11-83)



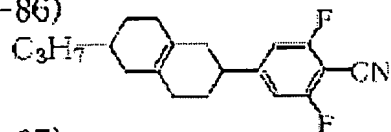
(2-11-84)



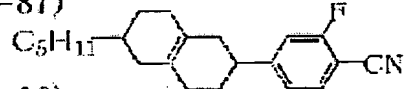
(2-11-85)



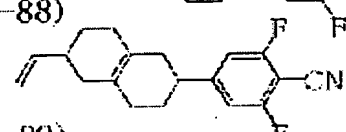
(2-11-86)



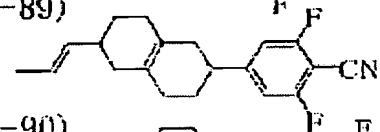
(2-11-87)



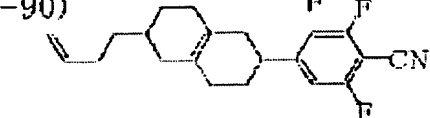
(2-11-88)



(2-11-89)



(2-11-90)

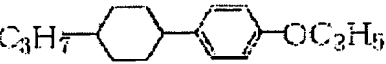

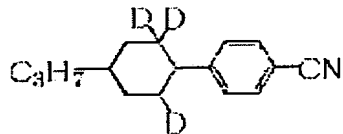
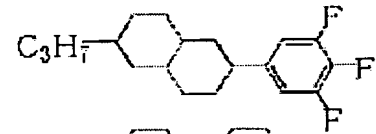
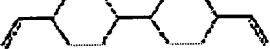
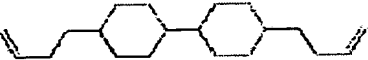
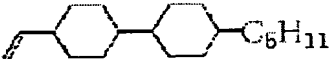

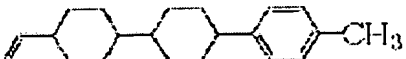



[0333]

(Example 12)

A nematic liquid crystal composition (3-12) was prepared from

[Chemical Formula 118]

(3-1201)		7 wt %
(3-1202)		7 wt %
(3-1203)		13 wt %
(3-1204)		7 wt %
(3-1205)		3 wt %
(3-1206)		15 wt %
(3-1207)		10 wt %
(3-1208)		10 wt %
(3-1209)		14 wt %
(3-1210)		14 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 76.9°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 4.2

$\Delta n$  : 0.087

$\eta$  : 10.9 c.p.

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 8  $\mu\text{m}$ ):

$V_{th}$  : 2.11 V

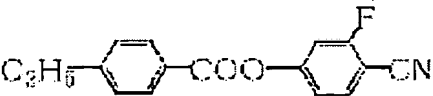
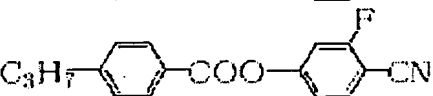
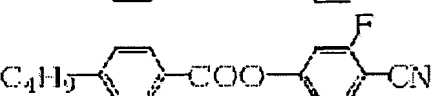
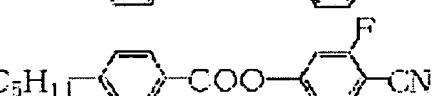
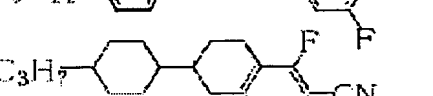

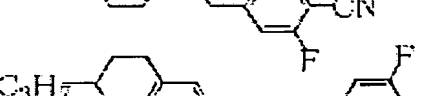
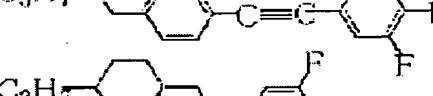
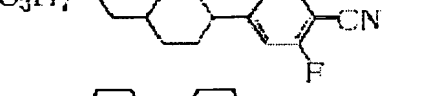
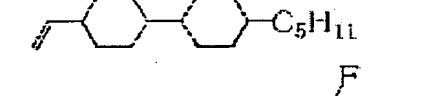
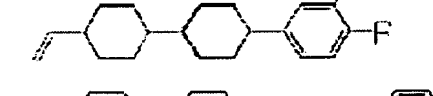
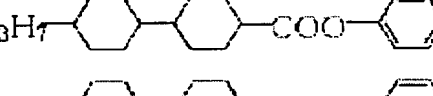
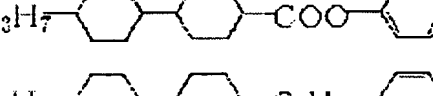
$\gamma$  : 1.13

[0334]

(Example 13)

A nematic liquid crystal composition (3-13) was prepared from

## [Chemical Formula 119]

(3-1301)		8 wt %
(3-1302)		5 wt %
(3-1303)		16 wt %
(3-1304)		7 wt %
(3-1305)		8 wt %
(3-1305)		3 wt %
(3-1306)		7 wt %
(3-1307)		3 wt %
(3-1308)		8 wt %
(3-1309)		19 wt %
(3-1311)		6 wt %
(3-1312)		6 wt %
(3-1313)		4 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

T<sub>N-I</sub> : 84.5°C

$T_{-N}$  : -70. °C

$\Delta\epsilon$  : 20.4

$\Delta n$  : 0.133

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 0.82 V

$\gamma$  : 1.27

Display characteristics of the STN-LCD having a twist angle of 240 degrees

$V_{th}$  : 1.90 V

$\gamma$  : 1.018

$\Delta(V_{th})/\Delta(T)$  : 1.5 mV/°C ( $T=5$  to 40°C)

[0335]

The STN liquid crystal display device having a twist angle of 240 degrees had a driving voltage of 1 V or less, and also exhibited small concentration dependency of the driving voltage, fast response characteristics, and display characteristic which are superior in high-frequency time division characteristic due to sharpness.

[0336]

The following nematic liquid compositions are prepared.

[0337]

In the same manner as in the case of the nematic liquid crystal composition (3-13), except that the respective compounds (2-13-01) to (2-13-90) described below were used in place of the compound (3-1306) in the nematic liquid crystal composition (3-13) of this Example, nematic liquid crystal



compositions (3-13-01) to (3-13-90) were prepared.

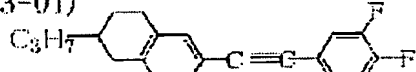
[0338]

The display characteristics of these nematic liquid crystal compositions (3-13-09) to (3-13-90) showed good results, similar to this Example.

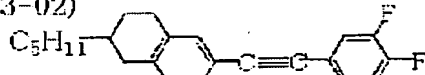
[0339]

[Chemical Formula 120]

(2-13-01)



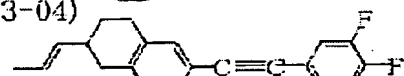
(2-13-02)



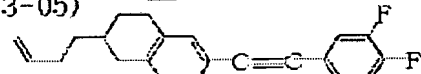
(2-13-03)



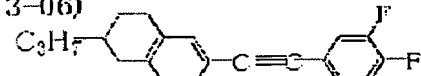
(2-13-04)



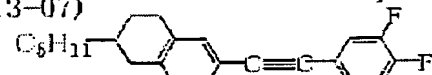
(2-13-05)



(2-13-06)



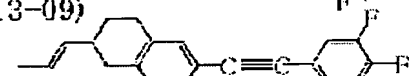
(2-13-07)



(2-13-08)



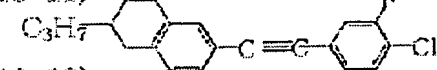
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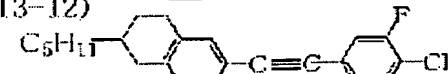
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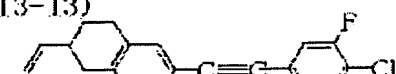
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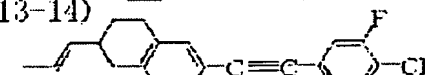
(2-13-12)



(2-13-13)



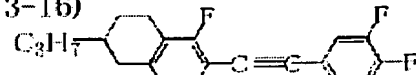
(2-13-14)



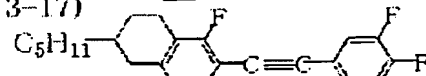
(2-13-15)



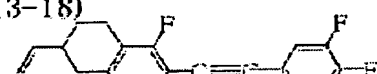
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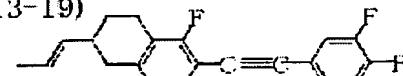
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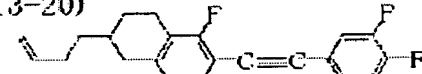
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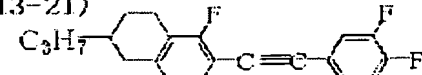
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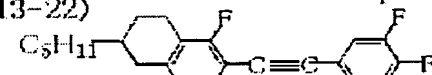
(2-13-20)



(2-13-21)



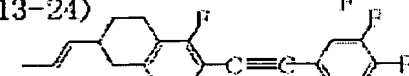
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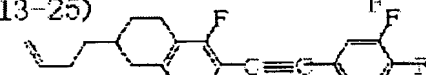
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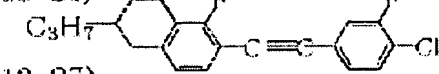
(2-13-24)



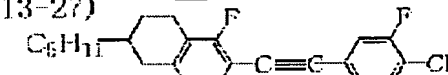
(2-13-25)



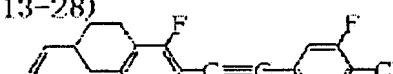
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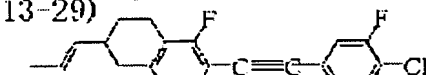
(2-13-27)



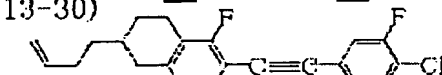
(2-13-28)



(2-13-29)

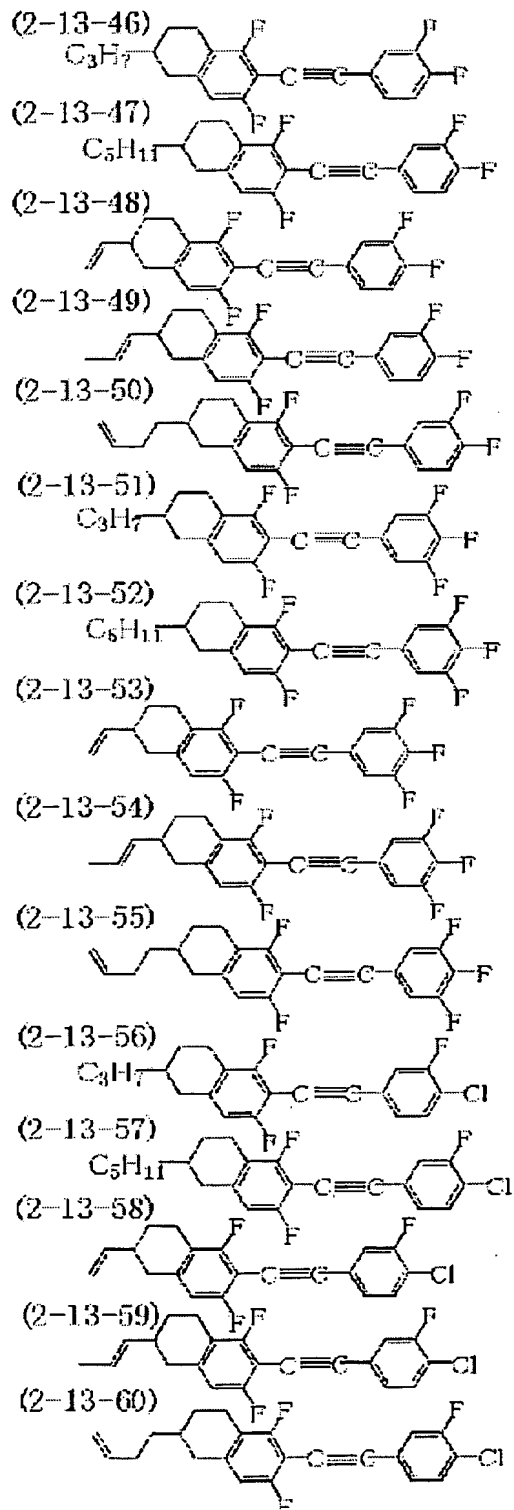
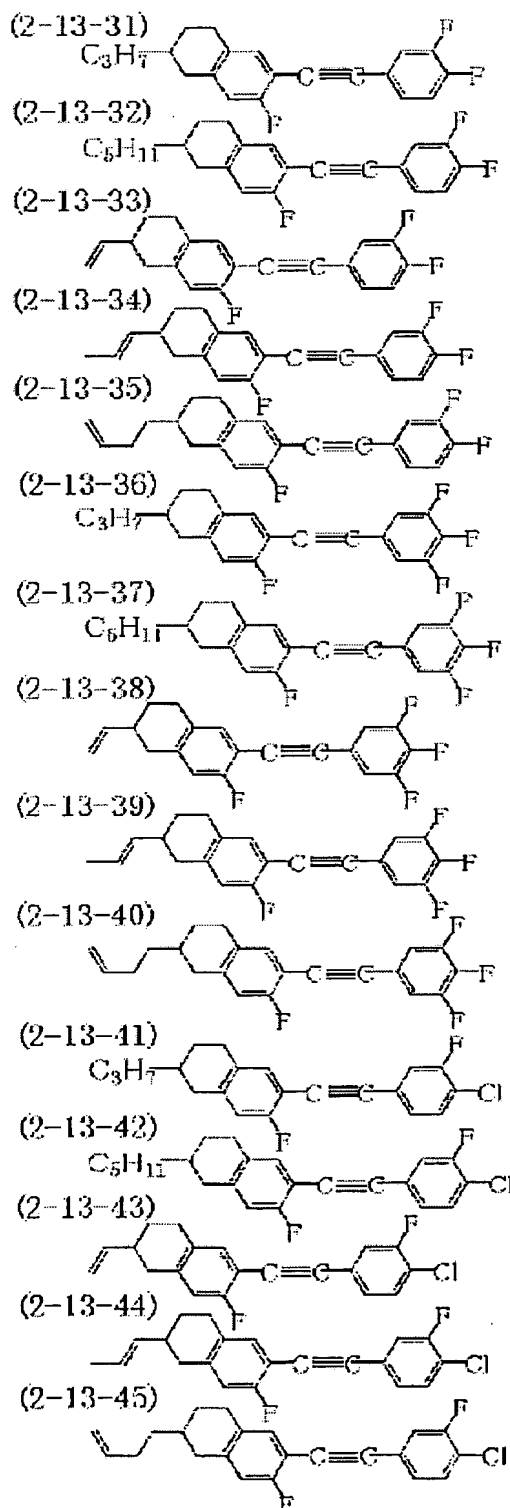


(2-13-30)



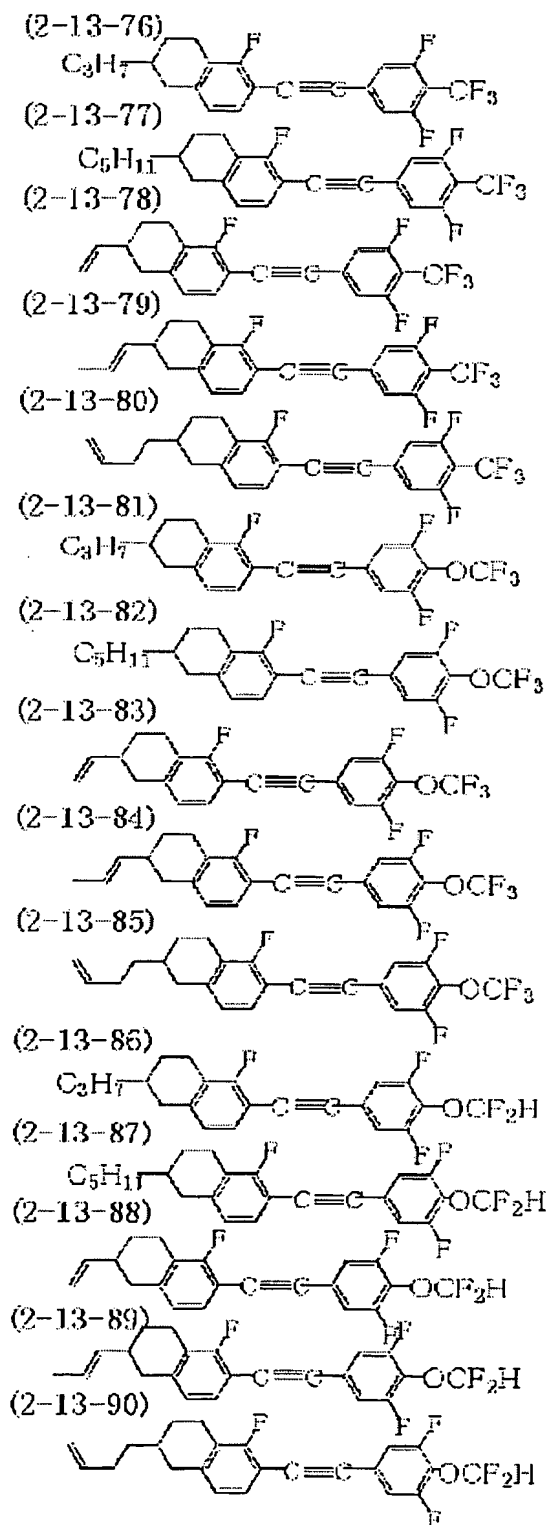
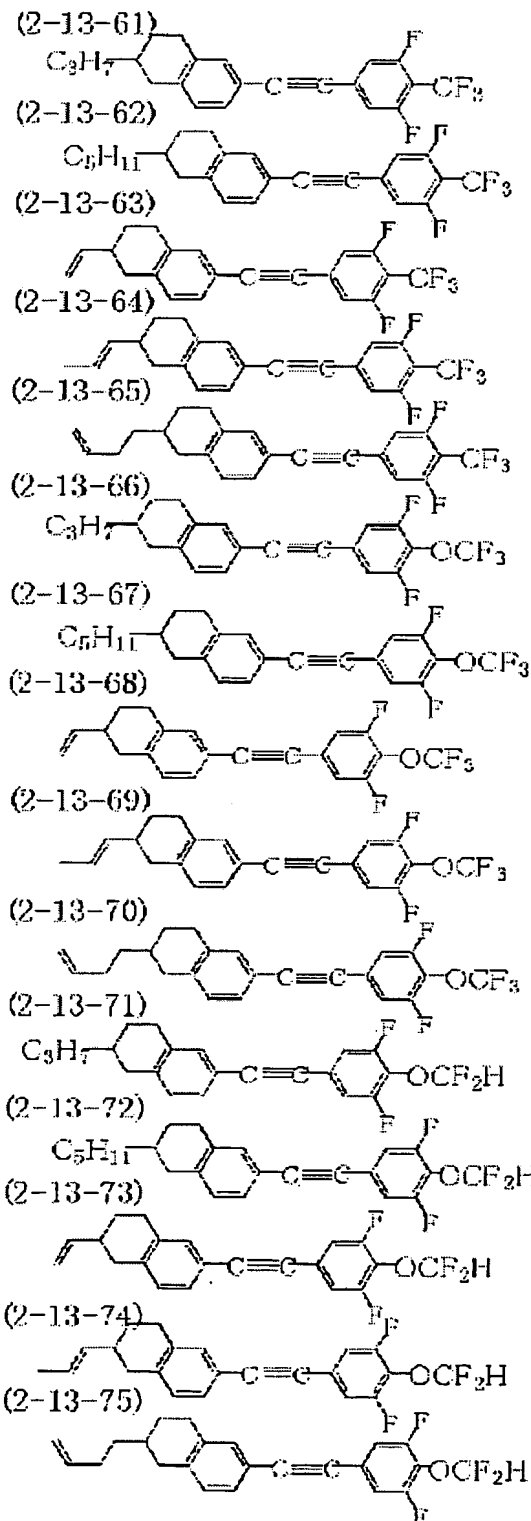
[0340]

[Chemical Formula 121]



[0341]

[Chemical Formula 122]



[0342]

(Example 14)

A nematic liquid crystal composition (3-14) was prepared from

[Chemical Formula 123]

(3-1401)		8 wt %
(3-1402)		5 wt %
(3-1403)		16 wt %
(3-1404)		7 wt %
(3-1405)		5 wt %
(3-1406)		5 wt %
(3-1407)		10 wt %
(3-1408)		17 wt %
(3-1409)		7 wt %
(3-1410)		6 wt %
(3-1411)		7 wt %
(3-1412)		7 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 92.2°C  
 $T_{-N}$  : -40. °C  
 $\Delta\epsilon$  : 18.8  
 $\Delta n$  : 0.142

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.00 V  
 $\gamma$  : 1.15

Display characteristics of the STN-LCD having a twist angle of 240 degrees

$V_{th}$  : 1.04 V  
 $\gamma$  : 1.033

[0343]

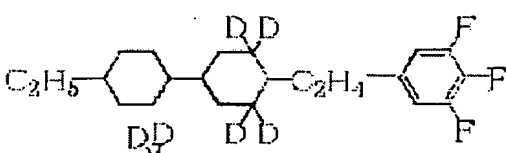
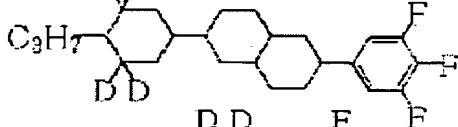
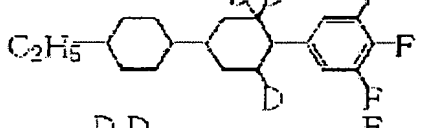
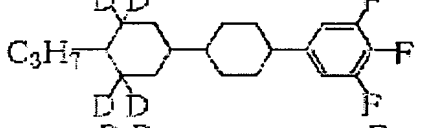
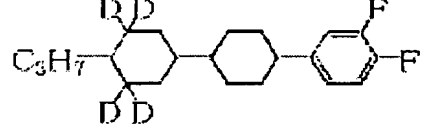
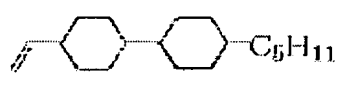
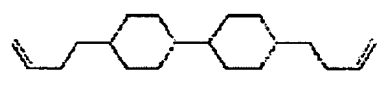
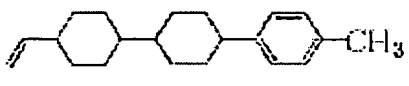
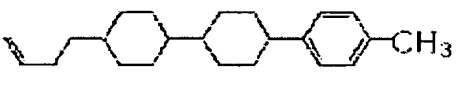
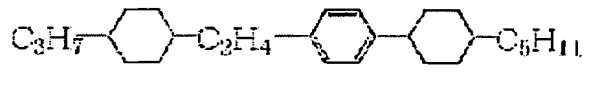
The STN liquid crystal display device having a twist angle of 240 degrees had a driving voltage of 1 V or less, and also exhibited small concentration dependency of the driving voltage, fast response characteristics, and display characteristic which are superior in high-frequency time division characteristic due to sharpness.

[0344]

(Example 15)

A nematic liquid crystal composition (3-15) was prepared from

[Chemical Formula 124]

(3-1501)		10 wt%
(3-1502)		10 wt%
(3-1503)		10 wt%
(3-1504)		10 wt%
(3-1505)		10 wt%
(3-1506)		10 wt%
(3-1507)		10 wt%
(3-1508)		10 wt%
(3-1509)		10 wt%
(3-1510)		10 wt%

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 106.2°C

$T_{-N}$  : -70. °C  
 $\Delta\epsilon$  : 3.4  
 $\Delta n$  : 0.075  
 $\eta$  : 18.3 c.p.

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 2.60 V  
 $\gamma$  : 1.15  
 $\tau_r = \tau_d$ : 21. msec

[0345]

This nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_{-N}$  is low. Also because this nematic liquid crystal composition has high resistivity and high voltage holding ratio after the heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker. This nematic liquid crystal composition further shows a value of optical sharpness near 1.12 that is the limit of TN-LCD liquid crystal shown in the literature "High-speed Liquid Crystal Technology" (p.63, CMC Publication). Thus it can be understood that this liquid crystal composition is useful for high-frequency multiplexing drive.

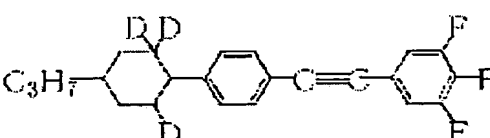
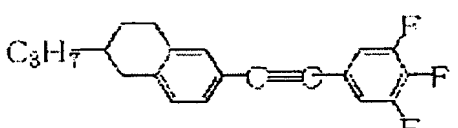
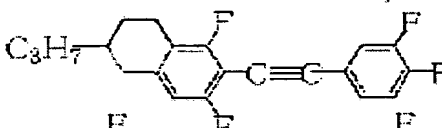
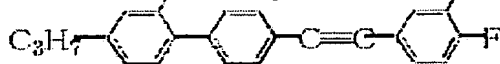
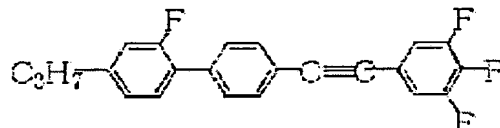
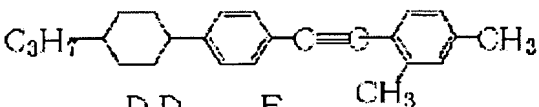
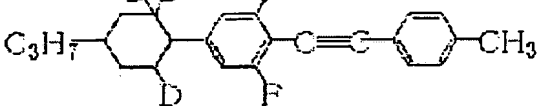



[0346]

(Example 16)

A nematic liquid crystal composition (3-16) was prepared from

[Chemical Formula 125].

(3-1601)		10 wt %
(3-1602)		10 wt %
(3-1603)		13 wt %
(3-1604)		17 wt %
(3-1605)		15 wt %
(3-1606)		10 wt %
(3-1607)		10 wt %
(3-1608)		15 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 80.9°C

$T_{-N}$  : -30. °C

$\Delta\epsilon$  : 10.1  
 $\Delta n$  : 0.260  
 $\eta$  : 42.8 cp

Reliability characteristics of liquid crystal composition

Resistivity before heating acceleration test:  $4.9 \times 10^{12}$

$\Omega \cdot \text{cm}$

Resistivity after heating acceleration test:  $3.1 \times 10^{12} \Omega \cdot$

cm

Voltage holding ratio before heating acceleration test:

99.0%

Voltage holding ratio after heating acceleration test:

98.2%

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 8  $\mu\text{m}$ ):

$V_{th}$  : 1.62 V

$\gamma$  : 1.15

$\tau_r = \tau_d$  : 49. msec

$\Delta(V_{th})/\Delta(T)$  : 2.3 mV/ $^{\circ}\text{C}$  ( $T=0$  to  $50^{\circ}\text{C}$ )

[0347]

This nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_N$  is low, and has such features as the capability to improve the response characteristic because the viscosity  $\eta$  is low or the value of  $\Delta n$  is larger and a dielectric constant anisotropy  $\Delta\epsilon$  is larger in comparison to the viscosity  $\eta$ . Also because this nematic liquid crystal composition has high

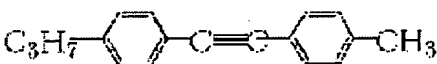
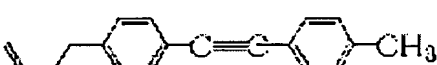
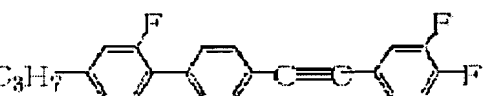
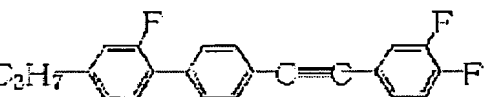
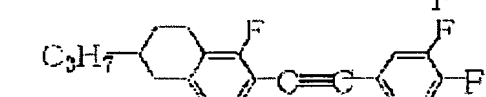
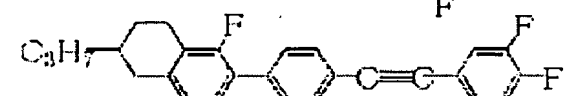
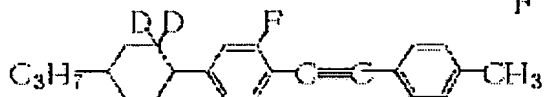
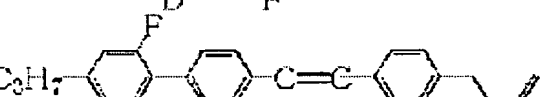
resistivity and high voltage holding ratio after the heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker. This nematic liquid crystal composition further shows a value of optical sharpness near 1.12 that is the limit of TN-LCD liquid crystal shown in the literature "High-speed Liquid Crystal Technology" (p.63, CMC Publication). Thus it can be understood that this liquid crystal composition is useful for high-frequency multiplexing drive. This nematic liquid crystal composition was used to make TN-LCD having cell thickness  $d$  of 1.9  $\mu\text{m}$  and display characteristics thereof were measured. A liquid crystal display device having a threshold voltage of 1.20 V and a response speed of 2.0 msec. was obtained.

[0348]

(Example 17)

A nematic liquid crystal composition (3-17) was prepared from

[Chemical Formula 126]

(3-1701)		15 wt%
(3-1702)		15 wt%
(3-1703)		15 wt%
(3-1704)		10 wt%
(3-1705)		8 wt%
(3-1706)		7 wt%
(3-1707)		15 wt%
(3-1708)		15 wt%

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$	:	112.0°C
$T_{-N}$	:	-70. °C
$\Delta\epsilon$	:	10.0

$\Delta n$  : 0.311

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 8  $\mu\text{m}$ ):

$V_{th}$  : 2.10 V

$\Delta(V_{th})/\Delta(T)$  : 2.6 mV/ $^{\circ}\text{C}$  ( $T=0$  to  $50^{\circ}\text{C}$ )

[0349]

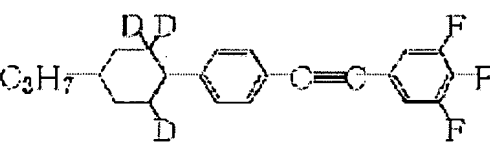
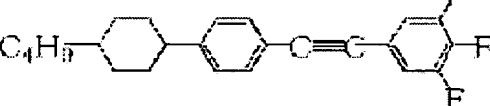
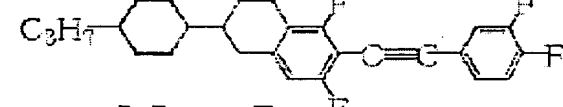
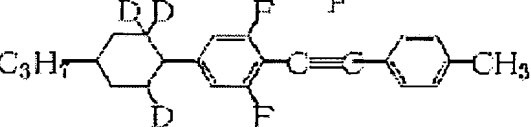
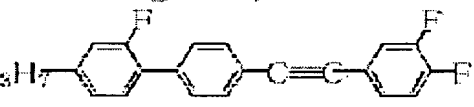
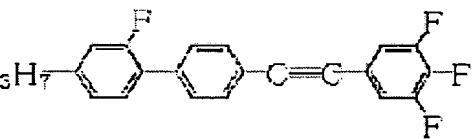

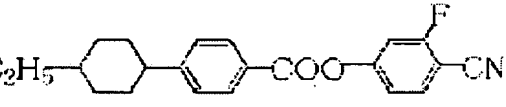
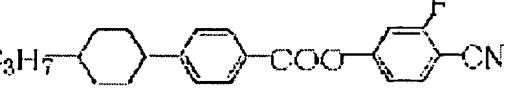
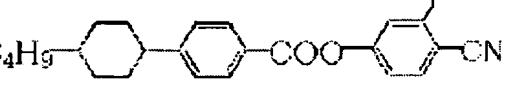
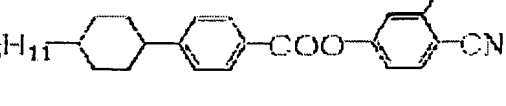
The nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_N$  is low, and has large  $\Delta n$  compared to the value of viscosity  $\eta$ , and is therefore capable of improving the response characteristics. It also has a large dielectric constant anisotropy  $\Delta\epsilon$  compared to the value of the viscosity  $\eta$ , and is therefore capable of improving the response characteristics even at a low driving voltage. Also because this nematic liquid crystal composition has high resistivity and voltage holding ratio after heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker. This nematic liquid crystal composition was used to make TN-LCD having cell thickness  $d$  of 1.6  $\mu\text{m}$  and display characteristics thereof were measured. A liquid crystal display device having a threshold voltage of 1.48 V and a response speed of 1.6 msec. was obtained.

[0350]

(Example 18)

A nematic liquid crystal composition (3-18) was prepared from

[Chemical Formula 127]

(3-1801)		10 wt %
(3-1802)		10 wt %
(3-1803)		10 wt %
(3-1804)		5 wt %
(3-1805)		10 wt %
(3-1806)		5 wt %
(3-1807)		10 wt %
(3-1808)		10 wt %
(3-1809)		10 wt %
(3-1810)		10 wt %
(3-1811)		10 wt %

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 164.4°C

$T_N$  : -50. °C

$\Delta\epsilon$  : 30.

$\Delta n$  : 0.243

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 1.24 V

$\gamma$  : 1.16

$\tau_r = \tau_d$ : 40. msec

[0351]

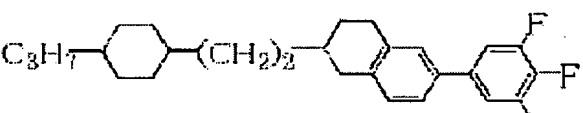
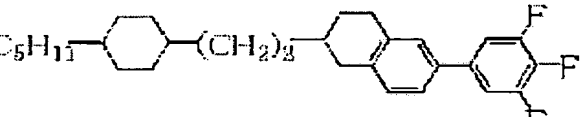
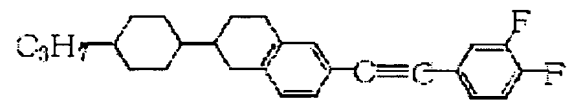
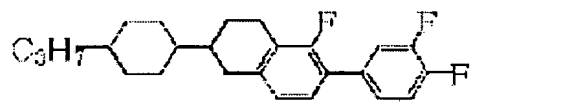
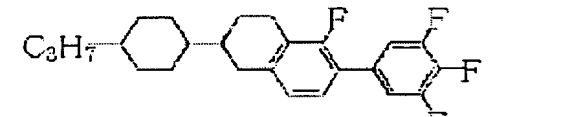
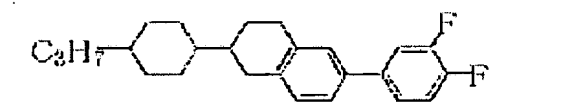
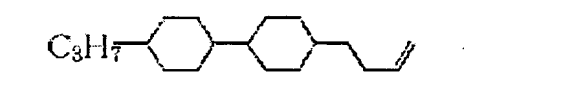
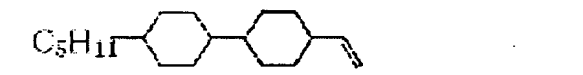
This nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_N$  is low, and has such features as the capability to improve the response characteristic because the value of  $\Delta n$  is larger. This nematic liquid crystal composition further shows a value of optical sharpness near 1.12 that is the limit of TN-LCD liquid crystal shown in the literature "High-speed Liquid Crystal Technology" (p.63, CMC Publication). Thus it can be understood that this liquid crystal composition is useful for high-frequency multiplexing drive.

[0352]

(Example 19)

A nematic liquid crystal composition (3-19) was prepared from

[Chemical Formula 128]

(3-1901)		14 wt%
(3-1902)		14 wt%
(3-1903)		10 wt%
(3-1904)		11 wt%
(3-1905)		10 wt%
(3-1906)		11 wt%
(3-1907)		15 wt%
(3-1908)		15 wt%

and various properties of this composition were measured. The results are as follows.

Physical properties of the liquid crystal composition

$T_{N-I}$  : 115.0°C

$T_{-N}$  : -70. °C



$\Delta\epsilon$  : 6.0

$\Delta n$  : 0.142

Display characteristics of the TN-LCD having a twist angle of 90 degrees (cell thickness 6  $\mu\text{m}$ ):

$V_{th}$  : 2.10 V

$\gamma$  : 1.14

Display characteristics of the STN-LCD having a twist angle of 240 degrees:

$V_{th}$  : 2.30 V

$\gamma$  : 1.033

$\Delta(V_{th})/\Delta(T)$  : 2.0 mV/ $^{\circ}\text{C}$  ( $T=5$  to  $40^{\circ}\text{C}$ )

[0353]

This nematic liquid crystal composition is capable of operating over a wide range of temperatures because  $T_{N-I}$  is high and  $T_N$  is low. Also because this nematic liquid crystal composition has high resistivity and high voltage holding ratio after the heating acceleration test, it can be understood that high thermal stability is ensured. The active matrix liquid crystal display device that employs this composition as the basic constituent material has excellent characteristics with less leak current without occurrence of flicker. This nematic liquid crystal composition further shows a value of optical sharpness near 1.12 that is the limit of TN-LCD liquid crystal shown in the literature "High-speed Liquid Crystal Technology" (p.63, CMC Publication). Thus it can be understood that this liquid crystal composition is useful for high-frequency multiplexing drive. The STN liquid

crystal display device having a twist angle of 240 degrees exhibited small concentration dependency of the driving voltage, fast response characteristics, and display characteristics which are superior in high-frequency time division characteristic due to sharpness.

[0354]

(Example 20)

The nematic liquid crystal compositions of the present invention (3-09), (3-16), (3-17), (3-18) and (1-13) to (1-16) can be used in light scattering type liquid crystal display. Application Examples will be described in detail below. It should be understood, however, that the present invention is not limited to these Examples.

[0355]

A light modulation layer forming material of uniform solution was prepared by mixing 80% of the liquid crystal composition described above as the liquid crystal material, 13.86% of HX-220 (manufactured by Nippon Kayaku Co., Ltd.) as a polymer-forming compound, 5.94% of lauryl acrylate, and 0.2% of 2-hydroxy-2-methyl-1-phenylpropan-1-one as a polymerization initiator. An empty cell measuring 50×50 mm, that was formed by two ITO electrode glass substrates with spacers having mean particle size of 10  $\mu$ m interposed therebetween, was filled with this light modulation layer forming material in vacuum at a temperature 10°C higher than transition temperature of the uniform solution. This assembly was, with the temperature being kept 3°C higher than transition temperature of the

uniform solution, passed under a metal halide lamp ( $80 \text{ W/m}^2$ ) at a speed of  $3.5 \text{ m/min}$ , while irradiating with ultraviolet rays having energy density of  $500 \text{ mJ/cm}^2$  to cure the polymer forming compound, thereby to make a liquid crystal device having a light modulation layer consisting of the liquid crystal material and a transparent solid substance. Cut surface of the cured material, that was formed between the substrates of the liquid crystal device thus obtained, was observed with a scanning electron microscope, and the transparent solid substance formed in three-dimensional network structure from a polymer was recognized.

[0356]

The light scattering type liquid crystal display thus obtained operates in a wider temperature range than the light scattering type liquid crystal display of the prior art, shows response characteristic that is favorable for the display of moving pictures, and has high contrast and uniform display characteristics, indicating the usefulness for outdoor information panels such as sign board, display of clock, projection display apparatus and so on. Use of the nematic liquid crystal compositions (3-09), (3-16) and (3-17) is particularly useful for active addressing, use of the nematic liquid crystal composition (3-19) is useful for multiplexing drive and use of the nematic liquid crystal composition (3-18) is useful for high-temperature applications such as illumination apparatuses and laser addressing.

[0357]

(Example 21)

The nematic liquid crystal compositions of the present invention, particularly (3-09), (3-16), (3-17), (3-18) and (1-13) to (1-16) further have the following features.

Measurement of chromatic dispersion of birefringent index of these nematic liquid crystal compositions showed greater dispersion between wavelength 650 nm and 400 nm, with values of 1.15 and greater in some compositions. Such a liquid crystal material shows greater phase difference due to the difference in the wavelength of light, and is therefore useful for the new reflective type color liquid crystal display device that is based on the birefringence of the liquid crystal and the retardation plate and provides color display without using color filters.

[0358]

(Example 19)

The nematic liquid crystal compositions of the present invention, particularly (3-03), (3-06), (3-12), (3-15) and (3-16) further have the following features.

Assume the relaxation frequency given as  $\omega d = 2 \times 10^{12} \times S^{-1.4031}$  defined in terms of the liquid crystal constitution factor  $S = (\eta \times \langle a \rangle^3)^{-1}$  ( $\eta$  represents the viscosity (in cp) of the liquid crystal composition and  $\langle a \rangle$  represents the mean molecular length (in Å)), and assume that effective frequency  $F$  which acts on the liquid crystal display is determined by the frame frequency of the driving voltage applied to the liquid crystal composition or by the duty number. Then

relation of inequality  $1.0 \times 10^2 \geq \omega d/F \geq 5.0 \times 10^{-1}$  holds in the range of the operating temperatures. Thus it can be seen that the driving voltage does not vary in the range of frequencies that correspond to various time division schemes, or the driving voltage can be suppressed from increasing sharply in a low temperature region when the frequency of time division (duty number) increases. Such a characteristic is supposedly due to the molecular structure of a decahydronaphthalene-2,6-diyl group. As a result, use of the liquid crystal composition of the present invention makes it possible to make a liquid crystal display device having improved display characteristics. Better drive characteristic and better display characteristics were obtained with TN-LCD type and STN-LCD type liquid crystal display devices that process particularly large amount of information.

[0359]

[Effects of the Invention]

The nematic liquid crystal compositions of the present invention include, as an essential component, the liquid crystal component A that consists of the compounds represented by the general formulas (I-1) to (III-4) and, when mixed in the liquid crystal composition, such effects as the extended range of operating temperatures of the liquid crystal display due to the improvements in the co-solubility and in the storage at low-temperatures, reduction in the driving voltage, improvement in the temperature dependence of the driving voltage and thereby achieving relatively fast response

characteristic for a predetermined driving voltage. The design and temperature dependence of the birefringent index, dielectric constant anisotropy and elastic constant, light wavelength dependence of the birefringent index and frequency dependence of the dielectric constant anisotropy can also be improved. As a result, the nematic liquid crystal compositions of the present invention can be used in a liquid crystal display device of active matrix type, twisted nematic or super twisted nematic type. Also the present invention can provide a liquid crystal display element that provides color display by utilizing birefringence of the liquid crystal layer and retardation plate. Moreover, such an apparatus can be provided that is useful for light scattering type liquid crystal display having a light modulation layer which includes the liquid crystal material and the transparent solid substance.

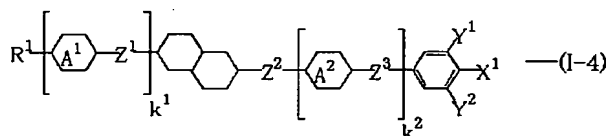
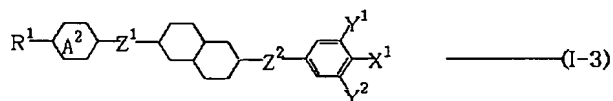
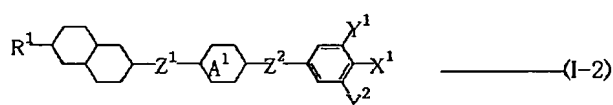
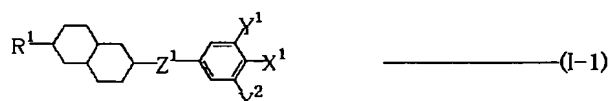
[Document Type] Abstract

[Abstract]

[Problems to be Solved by the Invention] To extend the operating temperature of the liquid crystal display by making improvements in the co-solubility and in the storage at low temperature, and to remedy the reduction in driving voltage and the change in temperature, thereby to attain comparatively fast response characteristics or to improve the response characteristics for a predetermined driving voltage. Also to improve various display characteristics of MIM or TFT-LCDs or STN-LCDs by a liquid crystal material having a desired birefringent index and to improve display characteristics of PN-CLDs or PDLCs by a liquid crystal material having a comparatively large birefringent index.

[Means for Solving the Problems] The present invention provides a nematic liquid crystal composition comprising a liquid crystal component A represented by the general formulas (I-1) to (I-4):

[Chemical Formula 1]



(wherein  $R^1$  each represents C1-12 alkyl;  $X^1$  each represents F or Cl;  $Y^1$  and  $Y^2$  each represents H or F;  $Z^1$  to  $Z^3$  each represents a single bond,  $-\text{COO}-$ , or  $-\text{CH}_2\text{O}-$ ; rings  $A^1$  and  $A^2$  each represents 1,4-phenylene or 2,3-difluorophenylene; and  $k^1$  and  $k^2$  each represents 0, 1 or 2); 0 to 99.9% of a liquid crystal component B having a dielectric constant anisotropy of +2 or more; and 0 to 99.9% of a liquid crystal component C composed of a compound having a dielectric constant anisotropy within a range from -10 to +2; the sum total of said liquid crystal component B and said liquid crystal component C being within a range from 0 to 99.9% by weight; and a liquid crystal device using the same.

[Elected Drawing] None